MILK PRODUCTS

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"OLLETT" GOLD MEDALLIST, 1932
PROVINCIAL MILK ADVISORY OFFICER, MINISTRY OF
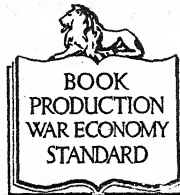AGRICULTURE AND FISHERIES

SECOND EDITION
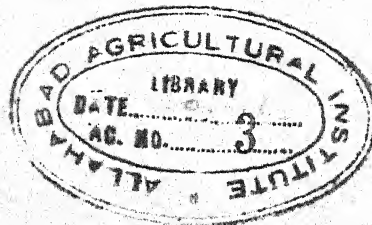WITH EIGHTY ILLUSTRATIONS

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BOOK
PRODUCTION
WAR ECONOMY
STANDARD

THIS BOOK IS PRODUCED
IN COMPLETE CONFORMITY WITH THE
AUTHORISED ECONOMY STANDARDS

PREFACE TO THE SECOND EDITION

THE second edition of *Milk Products* appears at a time when consideration of the various problems dealt with in the text calls for urgent attention. Recent disease outbreaks have tended to focus the spot-light on ice-cream, while commodities into which milk enters in one form or another are now receiving the publicity and attention which they have always merited, but, let us hasten to add, which they did not always receive.

It is indeed paradoxical that, when the nation could obtain as much milk as it wished, either for direct consumption or for manufacturing purposes, few seemed to know or care what was going on. Now, when our supplies are strictly limited, the whole nation suddenly becomes milk-conscious, for the first time in its history. One can only hope that this interest will be maintained when better times arrive. If that is, in fact, the case, then our present troubles will at least have yielded fruit.

Every effort has been made to bring the text of *Milk Products* right up to date, no easy task when the multiplicity of changing legislature and methods of production, etc., are taken into consideration. The structure of the volume has not been altered to any material extent, and the authors hope that it will receive as warm a welcome as did its predecessor.

W. C. H.

June, 1947.   H. H.

PREFACE TO THE FIRST EDITION

THE cordial reception accorded to the authors' previous publication, *Milk : Production and Control*, has encouraged them to embark upon the present volume, which is in the nature of a companion handbook. Incidentally, they sincerely trust that it will not suffer the fate of most classical sequels and be regarded merely as an anticlimax !

Milk Products is *not* a work on dietetics or nutrition, although these most important subjects receive due consideration throughout the text. It is rather a practical handbook which attempts to set out in reasonably concise form the various ancillary uses to which milk may be put, and to describe the processes of manufacture, together with desirable methods of control.

It may be thought that some of the manufacturing methods have received undue consideration, but the authors would like to point out that these descriptions were included only after due deliberation. *Milk Products* is essentially a Public Health text-book, and it was felt that, unless the official or officials responsible for controlling the output of these products from a Public Health aspect were fully cognisant of the detailed methods of manu-

facture, and at the same time familiar with the apparatus used in manu-
facture, adequate measures of control would obviously be impossible. It
is for those reasons that the processes have been considered at length, together
with the other factors which are held to be of general hygienic importance.

The chapters have in each case been compiled to a standard plan, so
that, wherever possible, adequate comparison may be made from section to
section. An attempt has been made to avoid unnecessary redundancy,
although, for the sake of clarity, some sections have been repeated in
summarised form in various parts of the volume. The legislation dea
with each milk product has received considerable attention.

In conclusion, the authors would like to tender their grateful thanks
H.M. Stationery Office for permission to incorporate on pages 113 and 125,
Tables 2 and 19 of the *Ministry of Agriculture and Fisheries Bulletin*, No. 57,
" Butter, Cream Cheese, and Scalded Cream." They are also indebted to
A. C. J. Browne, Esq., L.R.I.B.A., Architectural Assistant to the Southgate
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CHAPTER I

ICE-CREAM

Introductory

ICE-CREAM, which was looked upon as a luxury not so many years ago, has come to be universally regarded as almost a staple item of everyday diet, and the fact that it formed part of the normal rations of the United States serviceman when in this country, even during the years of shortages, had much to do with this change of opinion. Apart from its food value which will be discussed later, the production of ice-cream in increasing quantities forms a useful outlet for any surplus milk produced by the dairying industry of these islands. The trend of the milk industry for some time now has been to turn to the manufacture of one of the many milk products at present upon the market, as a means of disposing of any surplus. The present and increasing popularity of ice-cream undoubtedly provides an excellent and profitable means of utilising a large proportion of such milk, which, in normal times, would otherwise be unsaleable.

At this point it is perhaps unnecessary to stress the fact that a ban on the sale of ice-cream in the United Kingdom became operative following the issue of the Ice-cream (Prohibition of Manufacture and Sales) Order, 1942. The Ministry of Food has now authorised the manufacture and sale of this product with the limited supplies of materials available and ice-cream once again finds a ready sale amongst a public that has been without this article for three years. No doubt, at some future date, when the food supply situation becomes easier and all materials are available in sufficient quantities, more and better ice-cream will be manufactured and sold.

The fact that the dairying community in this country did not see fit to make full use of its available opportunities is a matter of considerable disappointment to those who have the welfare of the milk industry at heart. Particularly is this so when the potentialities of ice-cream manufacture as a means of increasing milk consumption are considered. For this reason it should be the aim of all members of the milk trade, when opportunity allows, in co-operation with ice-cream manufacturers, to combine their resources, with a view to benefiting the milk industry as a whole.

One reason for the absence of satisfactory headway was the fact that the public had not yet realised fully that the best ice-cream is scientifically prepared under hygienic conditions comparable with those which apply to the manufacture of other foodstuffs. They remembered the ice-cream of their childhood, produced in many instances under insanitary conditions, in dirty backyards or kitchens. It may therefore be stated that, apart from economic stress which formerly caused a serious reduction in the purchasing power of a large proportion of our population and the ban on its sale and subsequent dearth of suitable materials when this was raised,

the real reasons underlying the low consumption of ice-cream was the lack of confidence on the part of consumers with respect to the methods of manufacture, and their ignorance of its food value.

Much useful work has been and is still being carried out with a view to destroying such prejudices, but still further propaganda is required before ice-cream can be expected to take that place in the national dietary which it fairly merits.

Historical

Ice-cream has been manufactured for centuries and partaken of merely as a dainty or as a luxury, the product being specifically mentioned as one of the dishes supplied at a banquet given by Charles I, having been introduced into this country from France. It would appear that butter-ice, which contained milk or cream, was the forerunner of what we now know as ice-cream. Carlo Gatti, an Italian, was the first person to introduce the product to the public of this country, in 1860. The ice-cream retailed by Gatti was manufactured by means of a hand freezer, in the manner still practised to-day by many small vendors. Gatti boiled milk and eggs together in order to make a custard. This was frozen in a pewter container, surrounded with ice and salt as a freezing mixture. This container was rotated in the freezing agent by hand, and, to prevent the product adhering unduly to the sides of the receptacle, large wooden spatulas were periodically used to remove such adhesions. The ice-cream prepared by Gatti was sold in horns, or, as they are now known, "cornets" or "cones," the name "cornet" being derived from the Italian "corno," a horn. The horns used by Gatti were shaped in the form of the horn of a small animal and were manufactured by twisting a piece of biscuit dough around the finger prior to baking. Owing to public demand, Gatti's business speedily prospered and he began to look around to see how his trade could be extended. Requiring assistance to retail his wares over a larger area, he brought over peasants from his native country, whom he despatched with hand-barrows. He paid them a small monthly wage; housed and fed them. Apart from retailing the product, their duties included the freezing of the mix in the morning, before starting upon their rounds. The ice-cream was generally retailed in the form of a slab or brick, although horns or cornets were also sold. The common name given to ice-cream by the general public of those days was "hoky-poky," this name being a derivative of the cry of the Italian ice-cream vendors, "Gelati, ecco un poco," i.e. "frozen milk, behold a little."

At a later date, wafer biscuits were used to cover the bricks, these ice-cream wafers quickly ousting the horns or cornets from popularity. This was particularly noticeable in the case of adult consumers. In this way the trade was carried on by small vendors until after the War of 1914–18, when, from America, the home of modern ice-cream manufacture, machinery was imported to produce the article upon a large scale. With the continued steady increase in the quantity sold, there has been a remarkable evolution and improvement in the plant used for the manufacture of ice-cream. The methods of manufacture and the conditions under which the foodstuff is prepared have also shown considerable betterment, the result being that the trade is now firmly established in the hands of large and progressive companies. There are still many small vendors producing and retailing ice-cream, often in a very unsatisfactory manner, but it is apparent that

they have had their day, as they possess neither the capital nor the inclination to improve their manufacturing methods. In spite of the set-back to the trade occasioned by the last War it is apparent, judging from present production rates, that ice-cream has lost none of its appeal to the public palate and that its sales will further rapidly increase when conditions are normal once again.

Definition

It is extremely difficult to define the term "ice-cream" in a satisfactory manner, more particularly because of the variation in kind and quantity of the materials used in its manufacture. The definition given in a standard dictionary is:

"Ice-cream is cream, milk, or custard, which has been sweetened and flavoured and which has been frozen by means of a freezing mixture."

Ice-cream should be manufactured from milk, cream, and sugar, with or without eggs, and such an article should contain a considerable quantity of butter-fat. The Ice-Cream Association of Great Britain and Ireland recommended the following paragraph as a legal definition of ice-cream:

"A frozen product containing not less than 8 per cent. of milk-fat and not less than 10 per cent. of milk solids-not-fat."

On a further occasion, the same Association laid down that "standard" ice-cream should contain not less than 8 per cent. of butter-fat and not less than 18 per cent. total milk solids.

By far the greater proportion of the product commonly sold as ice-cream in this country is a very inferior article, containing not more and generally less than 3 per cent. of butter-fat and no eggs either liquid or dried. In this connection, the County Medical Officer of Health of Fife once stated:

"Ice-cream was a kind of trade-mark for a frozen mixture of unknown composition, the contents of which were only known to the makers and which might vary from day to day. Ice-cream has no recognised composition, and probably the great majority of ice-creams had no cream as the word was ordinarily understood."

Bearing this in mind, the Ice-Cream Association has suggested that such products should be designated and sold either as "milk ices" or "ices," the term "ice-cream" in these cases being a misnomer.

In America, a country where ice-cream is virtually a daily and universal item of diet, the United States Department of Agriculture bases its definition upon the composition of the finished article. The definition is as follows:

"Ice-cream is a frozen product made from cream and sugar with or without a natural flavouring and containing not less than 14 per cent. of milk-fat.

"Fruit ice-cream is a frozen product made from cream, sugar, fresh fruit and sound, non-rancid nuts and contains not less than 12 per cent. of milk-fat."

According to the Laboratory Manual issued in the United States by the International Association of Milk Dealers, plain ice-cream must have a butter-fat content varying between 8 to 14 per cent. according to the different States. The fat content of fruit and nut ice-cream is, however, lower than this.

The New York Sanitary Code (1941) gives the definition of ice-cream as:

"The pure, clean and wholesome frozen product made from milk products and with or without the use of sugar, water, eggs, harmless flavouring or colouring, or added stabiliser composed of wholesome edible material and in the manufacture of which freezing has been accompanied by agitation of the ingredients."

Under the Code, ice-cream must possess the following minimum composition:

(1) Milk-fat not less than 10 per cent. by weight.

(2) Total milk solids not less than 18 per cent. by weight.

Fancy ice-creams must not contain less than:

(1) Eight per cent. by weight of milk-fat.

(2) Fourteen per cent. by weight of total milk solids.

A frozen ice-cream mix is deemed to be adulterated if it contains more than $\frac{1}{2}$ per cent. of stabiliser or if it contains less than $1\frac{6}{10}$ lb. of total food solids per gallon. It must not contain more than 100,000 colonies of bacteria per gram in the melted product as determined by the standard plate count.

It appears a matter of paramount importance that some specific definition be formulated either by the Ministry of Health or the Ministry of Agriculture and Fisheries as to what may be termed "ice-cream." Particularly is this so when one considers the large and increasing quantities which are being consumed annually in this country now the ban on production has been lifted and, in addition, when the results of chemical analysis of many modern ice-creams are considered.

Under a Ministry of Food Order, No. 305 of 1945, the definition of ice-cream is given as:

" Ice-cream includes water ices and any article under whatever description it is sold which is so similar to ice-cream as to constitute a substitute therefor."

This definition is also set out in the Ice-cream (Heat and Treatment) Regulations, 1947.

It will be observed that, in the aforementioned definitions, no mention is made of the bacterial content of ice-cream. This is a serious omission. If ice-cream is to be officially defined, it is most essential that this definition should indicate not only the chemical composition of the article, but should also fix a practical bacterial standard.

Food Value

As already indicated, ice-cream, which was once considered a seasonal dainty, is now universally in season, being an almost everyday dish possessing a real food value, always provided that it is constituted of suitable, high-grade materials. It has been stated that ice-cream should be partaken of regularly for the following reasons:

(1) It is a safe, wholesome, nourishing food and is easily utilised by the body to produce energy, besides containing valuable vitamins which promote growth and health.

(2) It is no longer a delicacy, but can be obtained at all times and at a reasonable price.

Provided ice-cream is pure and uncontaminated, this might well be true, but the evidence of outbreaks of disease following the consumption of ice-cream leads one to believe that *all* ice-cream cannot be said to conform to these standards. Furthermore, a large quantity of the ice-cream sold in this country is manufactured from such poor, low-grade materials that the food value is extremely low.

It may be generally stated that food, to be really nutritious, must contain the following compounds:

(1) Proteins (nitrogenous compounds): Essential for body building.

(2) Fats: Supply heat and energy.

(3) Sugar constituents: Essentially heat and energy producers.

(4) Mineral matter (salts): Calcium and phosphorus salts essential for the growing tissues of the body.

(5) Vitamins: Necessary for normal growth.

All the above essentials are to be found in milk and also in ice-cream, particularly if the latter contains cream in addition to milk, together with added sugar. Therefore, ice-cream may be described as an excellent protective food, if suitably constituted. This should not, of course, be taken to mean that one's diet should consist solely of ice-cream, although this substance is one of the most attractive ways in which dairy products may be served. We have merely tried to indicate that ice-cream contains the elements upon which life may be sustained.

Genuine ice-cream, besides being extremely palatable, contains all the vitamins and calorific values of whole milk and cream, together with those of the added serum solids of milk and sucrose. Its mineral content is lower than that of milk but it is far in advance of butter as a source of calcium and phosphorus. An average portion of good-quality ice-cream contains twice the vitamin-A content of milk and four times that of butter, while it is a good source of vitamins B_1, E, and G. In addition, it possesses a high energy value and its proteins are more completely assimilated than those of most other foods. Gelatine, often used in the preparation of ice-cream, is a valuable protein food and aids the digestibility of the product by limiting the size of the milk protein curds formed in the stomach. Ice-cream supplies material to repair waste and injury and for the building of new tissues, while it possesses the advantage that it may be added to the dietary as a special privilege rather than as a basic foodstuff. So far as actual nutritive value is concerned, ice-cream, particularly as regards tissue building and the generation of energy, is much more useful than a large variety of articles popularly supposed to be foods of the highest value.

Ice-cream is of particular value in the dietary of sick persons and the under-nourished, such persons being generally willing to consume it when they would refuse other articles of food possessing a comparable nutritional value. Not only is it a highly palatable food which stimulates the secretion of saliva and gastric juices, but it is easily digested because it the fat has been finely dispersed by homogenisation, the curd particles formed in the stomach are smaller on account of the heat treatment and homogenisation to which the mix has been subjected. In addition to its palatability, ice-cream is also valuable in such cases, being, as already indicated, a fairly well-balanced food which, with the addition of fruit, can support life for a lengthy period in safety. In this connection, it is of some importance to note that an ordinary dish of good-quality ice-cream contains approximately twice as many calories as a glass of milk and four times as many as the conventional quantity of potatoes usually consumed, while, in addition, it contains a reasonable and varied quantity of proteins which are well-adapted for tissue-building purposes. One pint of good-quality ice-cream is equivalent in energy value to 7 eggs, 5 lb. of tomatoes, over $1\frac{3}{4}$ lb. of chicken or two-thirds of a pound of steak.

Ice-cream may also be used during convalescence as a vehicle for conveying to patients many other articles of food which would normally

be refused.   Thus, medicines, cod-liver oil, eggs and butter, etc., may be mixed with ice-cream, the low temperature and sweetness of the latter product disguising the original taste.

At this juncture, however, a word of warning as to the excessive consumption of ice-cream becomes necessary.   In the United States of America, this practice has transformed that country into a nation of dyspeptics. This has come about through the constant chilling of the membrane lining the digestive tract.   It will readily be understood that the excessive consumption of ice-cream with a view to obtaining a large amount of nutrition or even pleasure, or in order to reduce an overheated body temperature, is likely to bring about more harm than good.   Because of this, the low temperature of ice-cream has been urged as a serious objection to its use.   It is very true that the sudden introduction of a large quantity of cold material into the stomach is seldom beneficial, and may indeed be exceedingly harmful.   Ice-cream should therefore be eaten sufficiently slowly and in reasonable bulk to permit of an equalisation of temperature by the gastric circulation.   Unless the product is eaten with inordinate rapidity, the body is fully capable of carrying this into effect.   Adults, as a rule, eat ice-cream slowly, it being found that only children indulge in a rapid demolition of the article.

Bacteria in Ice-cream

Ice-cream, in a similar manner to milk or cream, is open to two kinds of contamination:

(1) Chemical.
(2) Bacteriological.

Chemical contamination is easily detectable and can either be avoided or limited, while any serious contamination can be dealt with under the powers provided by the Food and Drugs Act, 1938.   On the other hand, bacteriological contamination is much more difficult to control.   The milk, the milk products or other ingredients used are the chief sources of the bacteria found, particularly if the mix is inefficiently pasteurised or is not pasteurised at all.   In a *System of Bacteriology*, issued by the Medical Research Council, it is stated:

"The bacterial content of ice-cream depends largely on that of the cream and condensed milk, and it is more variable.   The putrefactive types will develop relatively more rapidly than the lactic acid types at the low temperature of the ice-cream, and if it is kept long before use it may contain objectionable products of bacterial metabolism.   Pathogenic organisms are sometimes found in ice-cream made from unpasteurised cream."

Dukes has also stated:

"Bacteriological examination has frequently revealed gross bacterial contamination in ordinary ice-cream."

Several further instances of the bacterial contamination of ice-cream may be cited.   During an investigation of the ice-cream supplied in the City of Bristol, carried out some years ago, samples were examined by Professor Walker Hall, who reported:

"Out of seventy-two samples examined, forty-seven contained organisms of various types, seven yielded large numbers of streptococci, one contained tubercle bacilli, and twenty-nine possessed an excess of extraneous matter."

His report goes on to state:

"It is evident that ice-cream supplies are unsatisfactory from a public health standpoint. Perhaps it is not fully realised how the consumption of ice-cream has increased of late and how closely it is associated with the necessity for using clean and pasteurised milk. The finding of virulent streptococci in one of the samples led to the revelation that the ice-cream producer was using milk from a supply previously reported as 'streptococcal.' "

During the summer of 1935, a special test was carried out in the City of Westminster, in the course of which ten samples of ice-cream were submitted for bacteriological examination. Eight of the samples did not reach the imposed standard, and the bacteriologist stated that the examinations revealed:

"An excessive number of organisms which appear to indicate the need for greater cleanliness of the materials and the methods of preparation."

Efficient pasteurisation of the mix will result in a considerably reduced bacterial content, but, as in the case of milk, much of the ice-cream sold in this country is unfortunately treated during its manufacture by what may be termed "commercial processing," which cannot, in many cases, be termed efficient.

Bacteria found in ice-cream may be divided into two classes:

(1) Pathogenic bacteria.
(2) Non-pathogenic bacteria.

(1) Pathogenic Bacteria.—While it is probable that the majority of pathogenic organisms found in ice-cream have an initial human origin, this fact does not rule out organisms of animal origin, such as the *Mycobacterium tuberculosis*, *Brucella abortus* and *Streptococcus mastiditis*, which may be present in the milk or cream used during manufacture. Although there are no records of any human infection by such organisms following the consumption of ice-cream, the possibility should not be lightly dismissed. Particularly is this so if the mix is not efficiently pasteurised. Organisms of human diseases may also obtain entrance to the product after production and prior to sale. Hæmolytic streptococci, typhoid bacilli, and the causative organisms of scarlet fever and dysentery have all been transmitted by ice-cream, causing disease among the consumers of such infected articles, instances of which will be detailed later. Several cases of food poisoning following the ingestion of ice-cream have been reported, due to infection of the product by *Bacillus aertrycke*, by *Staphylococcus aureus* and by organisms of the Salmonella group.

It is sometimes stated that continuous cold storage such as that to which ice-cream is subjected will prevent the development or even destroy pathogenic bacteria. It has been frequently demonstrated that freezing and the low storage temperatures of ice-cream provide no absolute protection against the presence of pathogenic organisms and, in this connection, the following points deserve consideration:

(1) It has been demonstrated by Davis that hæmolytic streptococci remain alive in ice-cream for at least eighteen days without any appreciable diminution in their number or virulence.

(2) Prucha and Brannan have found live typhoid organisms in artificially infected ice-cream stored at —4° F. after a period of over two years.

(3) Wallace and Creuch, in 1933, demonstrated the fact that *Salmonella enteritidis* and *aertrycke*, *Brucella abortus*, *Brucella melitensis* and *Mycobacterium tuberculosis* survived in ice-cream, stored at —10° F., for a period longer than two and a half years.

(2) **Non-pathogenic Bacteria.**—It is fortunate that the non-pathogenic organisms found in ice-cream considerably outnumber those of the pathogenic group. The main types of non-pathogenic bacteria found in ice-cream are similar to those found in milk. Chief among these are the organisms of the lactic-acid group, which are present in all milk and milk products, pasteurised or otherwise. *Bacillus coli* and *Bacillus aerogenes* may also be present. Even when the mix has been pasteurised for thirty minutes at 145° F., Fabian and Coulter have demonstrated that from 2 per cent. to 22 per cent. of the coli-aerogenes group may survive. Some types may even survive efficient processing at a temperature of 150° F. Although such organisms are not responsible for any outbreaks of disease among consumers of ice-cream, their presence in excessive numbers is unnecessary and must be deplored. Such contamination could certainly be avoided if clean milk, or a good milk powder, or cream possessing a low bacterial content, were used in the manufacture of the product and if the sterilisation of the utensils was adequate.

Sources of Bacteria

Ice-cream may become bacterially contaminated at any or all of the following points during manufacture and distribution:

(1) From raw materials.
(2) During manufacture.
(3) During packing.
(4) During distribution.
(5) By personnel.
(6) By the consumer.

(1) **Raw Materials.**—The principal sources of contamination of the raw mix are the milk products, particularly any cream or butter which may be used during manufacture. Efficiently pasteurised cream or milk should be satisfactory, but butter is frequently contaminated, particularly on the surface of large blocks. The bacteriological quality of the butter must always be borne in mind, particularly if manufactured from raw cream, since it may then contain large numbers of bacteria. Whole-milk powder, which is sometimes used, generally contains few bacteria, owing to the method of manufacture. Skimmed-milk powder, on the other hand, may produce a serious bacterial propagation unless great care has been taken in its handling throughout the powdering process. Sugar is not generally regarded as a source of bacterial contamination but as some investigators have reported high bacterial contents, this material should not be overlooked as heat-resistant organisms may be present. Eggs, both fresh and dried, nuts, flavourings and colouring matters have, at various times, been proved to be sources of bacterial contamination. Gelatine, which is commonly employed to give consistency, may be the cause of an exceedingly high bacterial content, if it is of poor quality. Bacteriologists have reported bacterial counts of from 10 to 100 millions per gram of gelatine and for this reason only the highest quality material should be used. As decomposition does not quickly betray itself in this frozen food, stale milk may be used in the manufacture of ice-cream, a practice which may result in the presence of large numbers of bacteria.

Pasteurisation, *not* sterilisation, is employed in the large-scale manufacture of ice-cream, and, because of this, it is particularly necessary to ensure that the raw materials are free from large numbers of bacteria. The heat treatment of the mix must necessarily be limited both as regards time and temperature, otherwise there is danger of a cooked flavour developing. It is to be expected, therefore, that the lower the initial count of the raw materials, the lower will be the final count of the product and the smaller the risk of toxins surviving, provided care is taken during *all* stages of manufacture to guard against further contamination. If pasteurisation is not carried out, the purity of the original ingredients and the method of manufacture assume even greater importance. In short, unless the raw materials are entirely free from blemish, there can be no confidence in the finished product.

(2) **Manufacture.**—Before ice-cream is ready for distribution and consumption, it has to pass through several processes, all or any of which may be the cause of contamination. These processes are:

(*a*) Pasteurisation.
(*b*) Homogenisation.
(*c*) Cooling.
(*d*) Ageing.
(*e*) Freezing.
(*f*) Premises and plant.

(*a*) *Pasteurisation.*—Owing to the fact that certain of the ingredients used in the manufacture of ice-cream exert a protective influence against heat, it is usual to employ a higher temperature than is the case with milk. It is now a legal requirement that the mix must be pasteurised at a temperature of 150° F. for thirty minutes or at 160° F. for ten minutes, and in some cases temperatures up to 170° F. are employed. The mix must be free from any " lumps," as the heat penetration of these masses will be retarded, particularly if they contain air. If the mix is lumpy, efficient pasteurisation of the whole will not be possible. The formation of foam in the holder should be avoided, as it is extremely difficult to maintain the foam at pasteurising temperature without the provision of air heaters above the surface of the mix. Valves, if badly designed, and long lengths of piping, if inefficiently cleansed, may be the cause of a high bacterial content. It is very important at this stage to avoid even the slightets contamination of the mix, as organisms may be distributed throughout the plant, to multiply where conditions are favourable. In modern plants, the mixing is carried out apart from the remainder of the plant, this practice tending to reduce the risk of contamination during treatment. Efficient sterilisation of the holder and other apparatus is, of course, essential if bacterial contamination is to be avoided.

(*b*) *Homogenisation.*—Fabian has stated that an apparent increase in the plate counts of ice-cream may occur, due to the dispersion of bacterial clumps during the homogenisation process. It is possible to avoid this by the use of ingredients of good quality which will be reasonably free from bacterial clumps; and by ensuring that the pasteurisation temperature is sufficient to destroy any such clumps which may be present. The efficient sterilisation of the homogeniser is also essential, while the packing

should be frequently renewed. It is desirable that the process should be carried out at a temperature approximating to that of the pasteurising process.

(c) *Cooling.*—The method of cooling is important. Not only is speedy temperature reduction essential to the reduction of bacterial growth, but it is also necessary to avoid contamination at this point. Bacterial growth is most probable at temperatures ranging between 70° and 110° F. It is therefore essential that, whatever method of cooling is used, the process should be such that a *rapid* reduction of the temperature of the product to between 35° and 40° F. will be ensured. Much of the high bacterial content commonly found in the cottage-manufactured type of ice-cream is due to the slow cooling of the mix, the usual method being to stand the container holding the mix in water overnight, cooling being retarded owing to the bulk of the product.

Surface coolers are commonly employed for reducing the temperature of the product to the level at which it is to be matured, and it is essential that such apparatus should be afforded protection from contamination. It should be remembered that the mix, if it has been efficiently pasteurised, will have lost the greater portion of its initial bacterial content, thereby becoming extremely liable to recontamination. Metal plates which protect the cooler, or some other means of protection such as a glass case to which a stream of purified air is supplied, are essential. As with milk coolers, inefficient cleansing and sterilisation of the apparatus will lead to contamination of the product.

The best type of cooler is the "plate heat-exchanger," which, if efficiently cleansed and sterilised, ensures speedy cooling without risk of air-borne contamination.

(d) *Ageing.*—With the older type of ageing vat, contamination due to leaks through the insulation and faulty packings were often experienced. Modern, glass-lined ageing vats possess none of these faults, and with such plant the risk of any bacterial contamination is negligible. If a temperature of not more than 35° F. is maintained and the vats are of a modern type, there is little fear of bacterial contamination, but it is obvious that the ageing period should not be prolonged more than is actually essential, as, even at the low temperatures at which the mix is aged, bacterial multiplication is not entirely retarded.

(e) *Freezing.*—Bacterial contamination of the product by the freezer is a possibility which must not be overlooked. In the modern type of horizontal freezer in which the mix is whipped by a system of beaters and frozen by contact with a refrigerated jacket, sterilisation is often a problem, owing to the difficulty experienced in bringing the jacket to the temperature necessary if sterilisation is to be efficient. In addition, the beaters are liable to retain particles of solid matter if not properly cleansed. There does not appear to be any appreciable increase in the bacterial content of the product from the air whipped into the mix to produce overrun. On the other hand, the source of the air supply should be pure.

(f) *Premises and Plant.*—It is essential that the premises should be maintained in a scrupulously clean condition. This is particularly necessary in the case of walls, ceilings, floors, and fixtures.

The plant must be efficient in all respects, and no pockets, defective valve seatings, leaking joints or complex pipe-lines, whether or not such

are used intermittently, should be present. The apparatus should be arranged in such a manner as to prevent any of the mix remaining stagnant at any particular point, and should give as continuous flow as possible. This is not always easy, as the various processes may be proceeding at different rates. It is possible to arrange for pasteurisation and cooling to be carried on continuously, but these processes will proceed more rapidly than the ageing or freezing operations.

(3) **Packing.**—Brick-making and other packing machines form complex pieces of mechanism, although they can be efficiently cleansed and sterilised if sufficient care is exercised. If such care is not taken, serious risk of contamination exists. Little risk is involved in the packing of ice-cream in bulk, provided the cans are of suitable design and are washed and sterilised in a satisfactory manner.

(4) **Distribution.**—Ice-cream may be bacterially contaminated in several ways during distribution. The maintenance of a freezing temperature by means of ice and salt is open to many objections, the principal being the fact that ice is often seriously contaminated. Such risks are, however, negligible with the use of modern methods of refrigeration. There is little risk of packaged goods being contaminated if the vendor of such articles possesses efficient storage equipment which is maintained in a cleanly condition. With regard to ice-cream sold loose or used for the manufacture of wafers or cornets, danger does exist, particularly if the containers and utensils do not receive efficient cleansing and sterilisation. Containers may be seriously contaminated if stored in an unsatisfactory manner. One of the writers has discovered containers in water-closets and under beds in sleeping apartments. It is also a common sight to see the scoop by which the product is served in shops standing in a vessel of dirty water which, without doubt, contains large numbers of bacteria. The fingers of the vendor may infect the product, whilst the lids of the cans may not be replaced after serving has taken place, with the result that the ice-cream is exposed to any contamination which is present.

(5) **Personnel.**—However great is the care taken to ensure that ice-cream is produced and distributed in a cleanly manner, under conditions guaranteed to deter bacterial contamination, the risk of contamination by persons handling the product is constantly present. Infective persons or "carriers" of any infectious disease may be the cause of epidemics, many severe outbreaks of typhoid, paratyphoid, and scarlet fever having been traced to infection of the finished article by distributors.

(6) **Consumer.**—Contamination of the product by the consumer after purchase is possible and requires consideration. This may occur through dirty containers furnished by the customer (where the ice-cream is purchased loose), or by dirty, contaminated or infected spoons. Infected persons in the home may be the original cause of contaminating the containers or spoons, and in this manner such infection may be distributed among the other members of the household.

Ice-cream and Disease

Many outbreaks of disease due to ice-cream have occurred in the past and, in spite of improved methods of production and distribution, it is still

possible that many more will occur in the future. When the quantity of ice-cream consumed annually is considered, however, it will be seen that such outbreaks are relatively few in number. This fact must not be taken to indicate that a need for improvement in existing conditions of production and distribution does not exist. In many instances there *is* considerable room for such improvement, and the possibility of further outbreaks is too serious to allow any permissible standard short of the maximum. It should be possible for consumers of the product to be able to partake of it at *all* times without *any* risk of infection, and for this reason everyone concerned should not be satisfied until infection by means of ice-cream becomes a spectre of the past.

The *characteristics of an ice-cream epidemic* may be summarised as follows:

(1) The outbreak is usually explosive in character, but this does not always hold. A number of cases will be notified at the same time, these primary cases being in turn responsible for secondary infections. Two or more cases may develop in one family on the same day. After the first cases are notified, further notifications will be received from day to day.

(2) Investigation will show that a large number of infected persons will have consumed ice-cream purchased from the same vendor, or, if such vendor is also a wholesale manufacturer of the product, from several small distributors obtaining their supplies from the same source. The fact that all the consumers of an infected ice-cream supply are not affected may be accounted for as follows:

(a) The possession of a certain degree of immunity to the specific organism of infection by some consumers of the infected article.

(b) The fact that all the ice-cream does not contain the infecting organisms.

(3) It has been reported that the usual incubation periods of those diseases carried by ice-cream are somewhat shortened. This is probably due to the heavy infection of the article and the rapid absorption of the organisms.

(4) Most cases occur among excessive or constant consumers of the product, particularly children, although this may not always hold, as the appeal of ice-cream is now more or less universal.

(5) Outbreaks tend to occur in districts supplied by small vendors who do not pasteurise the mix or whose methods are not in accordance with modern hygienic requirements.

(6) When the infected supply is stopped, the outbreak quickly subsides.

It will be observed that, with certain minor variations, the characteristics of disease outbreaks due to ice-cream closely follow those usually associated with milk-borne epidemics.

Investigation of Epidemics

The usual procedure in tracing outbreaks of disease believed to be caused through the consumption of infected ice-cream is to secure data from the affected persons or their relatives, such data being collected and analysed in an attempt to locate the possible source of infection. The preparation of a *spot map* to indicate the district in which the cases have been notified is very useful in this connection. This will show at a glance the incidence of cases along a route followed by a particular distributor. Special care is necessary in securing data, as a seemingly trivial occurrence may point to a definite source of infection. The tracing of an outbreak is primarily one of elimination, in which one factor after another is excluded until the source of infection becomes obvious. If the data obtained points to the premises of a particular vendor or manufacturer, it may be found that one of the employees is suffering from the disease in question, or is a "carrier" of such disease. If no such infected person can be associated

with the product, extended enquiries must be made. Pathogenic organisms from human sources do not multiply to any extent in ice-cream, so that laboratory investigation of the product may be inconclusive.

In cases of suspected food-poisoning, similar enquiries should be made. Samples of the article in question should be submitted to the Ministry of Health for examination.

As before, the similarity to a milk-borne epidemic investigation will be observed.

Diseases transmitted by Ice-cream

Several outbreaks of infectious disease due to infected ice-cream have occurred, during the course of which large numbers of persons have become affected. Outbreaks of food poisoning have also frequently occurred. The diseases which have appeared in epidemic form are:

(1) Typhoid fever.
(2) Paratyphoid fever.
(3) Dysentery.
(4) Septic throat.
(5) Scarlet fever.
(6) Diphtheria.
(7) Food poisoning.

(1) **Typhoid Fever.**—This is one of the principal infectious diseases of human origin which has been transmitted by the consumption of infected ice-cream. The sources of outbreaks of this disease are:

(a) Persons suffering from the disease.
(b) "Carriers."
(c) Persons carrying the organisms upon their hands or clothing after having been in contact with an infected person or "carrier."

The fæces and urine both of infected persons and "carriers" are the chief sources of typhoid bacilli, the ice-cream being contaminated by the uncleanly habits of such persons during handling. Fly infection is also possible, the bacilli being conveyed by those insects from privies where the fæces and urine of affected persons have been deposited. In every epidemic of this disease believed to be due to the consumption of infected ice-cream, the possibility of a "carrier" should be borne in mind if no positive case of the disease can be found. A polluted water supply may be a contributory cause, particularly in country districts. The medical examination of all persons handling ice-cream, together with the appropriate blood tests, should be carried out where necessary.

In September, 1916, an outbreak of typhoid fever due to infected ice-cream, in which 200 cases were notified, was reported from the Rural District of South Shields. Of the total number of cases notified, 150 persons were proved to have partaken of the infected article. The product in question was prepared on insanitary premises, under conditions favourable to the transmission of infection. Typhoid fever had occurred on the premises at a time corresponding to the infectivity of the ice-cream. At Hendon, in July, 1917, seventeen cases of the disease were notified. The cause of the outbreak was proved to be ice-cream which had been infected by a "carrier." An outbreak occurred in Luton in the months of May to July, 1924, in which 120 cases were notified. A large number of the affected persons showed a history of having partaken of ice-cream from a street

vendor. Nothing suspicious was discovered at the premises where the ice-cream was manufactured. The blood serum of one of the vendor's assistants, who, incidentally, assisted in washing the utensils, yielded a positive agglutination reaction to *Bacillus typhosus*. The ingredients of the ice-cream were not incriminated. It is supposed, that the assistant suffered from an ambulatory form of the disease, although the method of contamination was not clearly established. A small outbreak occurred in August and September, 1927, in the Rural Districts of Alton and Petersfield and in the Petersfield Urban District. Eleven persons were affected, all of whom had partaken of ice-cream prepared in Petersfield. The ice-cream vendor also retailed milk, but no cases were notified among his milk customers. The ice-cream was without doubt the vehicle of infection, but the manner in which it acquired its infective properties was not ascertained.

Anderson has reported an interesting outbreak which occurred at Santa Margerita in the Balearic Isles, involving 287 cases. Ice-cream was proved to be the source of the epidemic, infected water, a "carrier" or the vanilla used as a flavouring agent being suspected.

A serious outbreak of the disease occurred in Aberystwyth in 1946 which was traced to a single barrel of ice-cream sold by a typhoid "carrier." One hundred and twenty-four cases were removed to hospital while, in addition, many holiday-makers were affected upon return to their own homes. There were three deaths. At Coatbridge, Lanarkshire, in the same year, an ice-cream vendor who was a "carrier" was the cause of 112 cases being notified. The ice-cream was otherwise satisfactory.

(2) **Paratyphoid Fever.**—Although the outbreaks of this disease due to infected ice-cream are not so common as those of typhoid fever, they have occurred, infected persons, "carriers," fæces and urine constituting the chief sources of the responsible organism. In June, 1923, thirty cases of paratyphoid B fever were notified in Wisbech and the surrounding district. There were no deaths. In nine cases, no information was elicited to suggest any particular source of infection. It was, however, established that the remaining twenty-one cases had all consumed ice-cream. A sample of the article in question was bacteriologically examined and an organism of a type found in human fæces was isolated. Two of the employees at the manufacturing premises were discovered to have suffered from paratyphoid fever a short time previously, but were not proved to be carriers. It is possible, however, that one or both were in an infective condition at the time of the outbreak.. The manner in which the ice-cream became infected was not determined. Anderson reports an outbreak of paratyphoid B fever at Aberdeen in 1925, in which twenty-three cases were traced to the consumption of ice-cream infected by a "carrier" of the disease. An outbreak involving sixty-three cases was reported from Norwich in July, 1926. There were no deaths. Of the persons affected, fifty-nine were proved to have consumed ice-cream prepared by a woman who was found to be a "carrier" of *Bacillus paratyphosus B*. The "carrier" was isolated and the outbreak subsided. Several cases of paratyphoid B. occurred in Southampton in 1937, and these were traced to ice-cream which contained the causative organisms. The product was infected by the proprietor and an employee who packed the ice-cream, both of whom were proved to be "carriers." An outbreak of this disease occurred in Perth during 1945 and was traced to ice-cream sold by an infected shop assistant.

(3) **Dysentery.**—The sources of this disease are similar to those of typhoid and paratyphoid fever, and the investigation of any outbreak suspected to have been caused through the consumption of infected ice-cream should be carried out in a similar manner. Only one outbreak has been recorded since the War of 1914–18. This occurred at Worcester, in June, 1930. Twenty-four cases were notified, with one death. All the patients, with one exception, probably a secondary case, had consumed ice-cream from a vendor, but no bacteriological proof was obtained of the existence of any infection within the suspected premises.

(4) **Septic Throat.**—Armstrong and Parron report that an outbreak of this disease occurred in Middlesburg, Vermont, U.S.A., in 1913. Sixty persons were affected, the cause being found to be the milk used in the manufacture of ice-cream consumed by the affected persons. As with milk, ice-cream may contain hæmolytic streptococci. Owing to the inefficient heat-treatment of the mix, such organisms may survive the pasteurising process. They may be similar in every respect to those which produce septic throat. No outbreaks of this disease due to the consumption of ice-cream have been reported in this country during the past fifteen years.

(5) **Scarlet Fever.**—The organisms associated with this disease gain access to ice-cream via persons suffering from scarlet fever or from contacts with infected persons. "Carriers" in the accepted sense of the term are not easily detected, due to the doubt which still exists as to the specific strains of *Streptococcus hæmolyticus* responsible for the disease. They undoubtedly do exist, while the organisms are capable of surviving for some considerable time apart from the infected person. In investigating any outbreak which may appear to be due to the consumption of ice-cream, "carriers" of hæmolytic streptococci should be sought out and prohibited from handling the article. A notable outbreak of this disease occurred in Flint, Michigan, in 1924. One hundred and sixteen cases were notified in the town, together with twelve in the immediate vicinity. Ice-cream prepared by one vendor had been consumed in 82 per cent. of the cases affected. The ice-cream had supposedly been pasteurised, but hæmolytic streptococci were found in the throat of the vendor.

(6) **Diphtheria.**—In 1937, an outbreak of this disease, affecting thirteen persons was notified from Glasgow. There were six deaths. Ice-cream purchased from an infected vendor was the causative food. Diphtheria spread by foodstuffs is extremely rare. The organisms isolated from the persons attacked and from the vendor and his family, who were "carriers" of the disease, were the highly-virulent type IV. No evidence is given as to the infection of the ice-cream itself as this does not appear to have been bacteriologically examined.

(7) **Food Poisoning.**—In the past, several outbreaks of food poisoning have been traced to ice-cream, and when it is considered how this foodstuff is commonly handled, such occurrences become quite understandable. From 1878 to 1911 six outbreaks of food poisoning were traced to the consumption of infected ice-cream. Savage, in a report on 112 outbreaks of food poisoning in the British Isles, states that six were attributable to ice-cream. An outbreak caused by infected ice-cream occurred at Stevington, in June, 1921. Forty-nine persons in all were affected, but none proved fatal. Martin reports an outbreak which occurred in 1923, due to

ice-cream infected with *Bacillus aertrycke*. The infection of the product in this instance occurred during the cooling process. In the same year, at Chepping Wycombe and in adjacent districts, an outbreak involving several hundred persons occurred. Ice-cream sold by an itinerant vendor was implicated, the wide distribution of the cases being accounted for by the fact that the vendor employed three assistants in the distribution of the product. One woman died, *Bacillus aertrycke* (*Type, Mutton*) being discovered in post-mortem material. Organisms were also found in the washings of an ice-cream container and also in the stools of one of the patients. The manner in which the ice-cream became infected was never discovered. In August, 1927, an outbreak was reported from Keynsham and Bath, in which 300 persons were affected, one of whom died. All had partaken of ice-cream from one particular source. The remainder of the ice-cream was examined and *Bacillus aertrycke* isolated. The manner in which the ice-cream became infected was again not discovered. The fæces of six of the patients showed the presence of *Bacillus aertrycke*. An outbreak was reported from the Llandilo Rural District in July, 1939, sixteen persons being affected, all of whom had eaten ice-cream purchased from one store. On account of the delay in summoning medical assistance, it was not possible to carry out an examination of the ice-cream, but when the stools of three of the cases were examined, two were found to contain organisms of the Salmonella (Aertrycke) group. Infection of the milk or cream used in preparation by a human "carrier," rodents, or flies was suspected. There were no fatal cases.

It will be seen from the foregoing accounts of disease outbreaks traced to the consumption of ice-cream, that the incidence of such outbreaks has materially declined during recent years. This is eminently satisfactory and appears indicative of improved methods of production and distribution, together with an enhanced quality of raw materials. In spite of this, the danger still exists and may at any time become intensified if control is allowed to slacken.

Ingredients used in the Manufacture of Ice-cream

Whatever the ingredients used in the manufacture of ice-cream—and these vary considerably—they should, as in all food products, be of the highest quality. War-time restrictions have prevented the use of almost all the pre-war constituents at the present time and the remarks which follow require to be considered in that light. When restrictions are removed the remarks will be applicable.

When ice-cream is prepared at home for domestic consumption, the mix generally consists of milk, sugar, and eggs in the form of a custard, which is frozen by a hand freezer and consumed within a short period. Small dealers generally use a mix consisting of:

(1) Whole, skimmed, or condensed milk.
(2) Sugar.
(3) Custard powder, ice-cream powder, or eggs.

Dried eggs may now be used under licence from the Ministry of Food. Certain conditions as to the use of this material are specified in the licence and these are set out on page 26. The addition of 1 per cent. of dried egg to the mix gives smoothness to the resultant ice-cream, improves the whipping qualities, ensures that the overrun is more speedily obtained and increases the quality and the food value. In addition, ice-cream containing

dried egg exhibits more resistance to melting at room temperatures. It is also officially recommended that greater use should be made of cereal fillers including soya flour.

Ice-cream powders are frequently used by small vendors, together with gelatine, which is added to give the product a certain consistency, and the ban on the use of all milk products in ice-cream manufacture with the exception of skimmed-milk powder has caused a great demand for such powders. As previously indicated, gelatine, particularly of poor quality, is a fertile source of bacterial contamination, and if such material is used, it should of necessity be of the highest standard.

The factors which govern the quality of gelatine, as set out by Heyl, are:

(a) Type of stock used in manufacture.
(b) The chemical treatment of the stock.
(c) The heat treatment of the stock.
(d) The pH of the stock.
(e) The moisture content of the gelatine.
(f) Quantity and types of metal salts present in the gelatine.
(g) The gel strength of the gelatine.

Gelatine is also useful inasmuch as it prevents the gradual crystallisation of the ice-cream during storage. Gum tragacanth and agar-agar are sometimes used as "fillers," but their presence is very undesirable. The use of this material is forbidden in one American State. Pectin added to the mix will improve the body of the ice-cream and it should preferably be used in combination with gelatine, the exact amount required depending upon the degree of stabiliser action required. This material should be added with the sugar before the mix is pasteurised.

Considerable variations exist in the mixes used in the modern ice-cream trade. Ice-cream is mainly of two types:

(1) The "Dairy" type—almost wholly a milk product.
(2) The "Custard" type—contains milk and occasionally cream, together with starchy fillers such as custard powder or cornflour.

Some typical dairy ice-cream mixes are given in the table below.

TABLE 1

	1	2	3	4
Milk	3½ pints	1½ pints	6¼ pints	5¾ pints
20 per cent. Cream	3 pints	5¾ pints	—	—
Unsalted Butter	—	—	1 lb.	20 ozs.
Sugar	6½ ozs.	23 ozs.	23 ozs.	13 ozs.
Skim Milk Powder	—	6 ozs.	7 ozs.	—
Sweetened Condensed Skim Milk	39 ozs.	—	—	24 ozs.
Gelatine	1 oz.	1 oz.	1 oz.	1 oz.

Mix formulæ are now based upon the percentage content of fat, serum solids, sugar, stabiliser, etc., as shown in specimen formula set out below:

10·0 per cent. butter-fat
8·0 per cent. serum solids
11·0 per cent. sucrose
5·0 per cent. corn sugar
0·5 per cent. dried eggs
0·5 per cent. stabiliser

35·0 per cent. total solids

This mix is used for the manufacture of continuous freezer ice-cream in the United States of America, and this type of formula ensures that the operator is more keenly conscious of mix composition. It also affords an opportunity for compounding the mix from a variety of dairy products.

Flavourings are added to the above as desired.

The fat content of dairy ice-cream is introduced either in the form of cream itself or by the incorporation of unsalted butter into the mix, together with the other necessary solids in the form of either condensed milk or skimmed milk powder. The total solids content is usually high to give the desired texture and is generally in the region of 33 to 35 per cent.

Gelatine is best added in solution. The common practice is to add one half-pound of powdered gelatine for each 100 lb. of mix, dissolving the gelatine in either the water or the milk, whichever is being used. The solution is strained and the whole then added to the mix. It is advisable to dissolve the gelatine in warm water and add it to the mix before pasteurisation. If this is done, the growth of the bacterial content of the gelatine will be greatly retarded.

Stabilisers or protective colloids are usually employed to obtain a smoother texture and body, not only in the freshly-frozen ice-cream, but also in the product during the period it is stored in the retailer's cabinet. In addition to imparting smoothness and improving texture a good stabiliser should prevent coarseness during storage, should be convenient to use and should not hinder the normal processing or freezing of the mix. In addition, its presence should not be noticeable when the ice-cream is eaten. Both animal and vegetable stabilisers may be employed. Gelatine, which is of animal origin, is commonly used in ice-cream mixes as already mentioned. It dissolves completely in the mix if care is taken to disperse the gelatine particles. This substance should be added when the temperature of the mix is somewhat below that needed for pasteurisation.

Of the vegetable stabilisers, starches, gums and sodium alginate are used. Starches, now often added to cheap ice-cream in the form of cereal fillers, swell and absorb large quantities of water and a smooth cream results. Gum will also absorb large quantities of water and will produce a smooth ice-cream but homogenisation is rendered difficult as the mix is likely to be stringy, while the body and texture of the finished article may be "sticky" or "soggy." During the last few years, a sodium alginate product has often been employed for stabilisation. While this article must be classed as a gum, its action is somewhat different from other gums and while it will absorb large quantities of water, it will not cause undesirable properties to develop in the mix. Extreme care is essential when this material is added to the mix, as the small, individual particles must be well dispersed when addition takes place. The temperature of the mix must not be lower than 160° F. when the material is added, mixed with a little cold water so that it will completely dissolve and leave no sediment behind. Sodium alginate causes the mix to increase in viscosity and this viscosity remains. There is no "filmy" after-taste in the mouth when the ice-cream is eaten, while faster whipping is rendered possible. Ice-cream containing this substance can be frozen immediately after cooling has taken place and approximately 0·3 per cent. is required to be added to the mix.

The quantity of sugar used in the mix is governed by the fat content. It has been found in practice that a high fat content does not combine well with a high sugar content. It is very essential that the two ingredients should be correlated. Tests have shown that one part of sugar to three parts of water is necessary for satisfactory sweetness, although ice-cream which possesses 20 to 30 per cent. less sugar than is normally used can be made sufficiently sweet by a reduction of the water content and by more air being whipped into the product. Dextrose, used to replace cane sugar, is more effectively sweet than the sugar it replaces. Further, the total solids content should be fixed, to prevent ice particles being formed and also to avoid a heavy, "stodgy" product.

Cream for ice-cream making should not contain more than 0·15 per cent. of acid, and preferably less. It is usual to age cream in a cold room from twelve to twenty-four hours in order to develop its whipping qualities. In some cases, a small quantity of salt is added to the cream to enrich its flavour, but this is not a practice to be recommended. Starchy or cereal "fillers" are not necessary in a rich mixture, but they are often added to cheapen the product by the addition of bulk, or to give body to what may be a naturally poor mixture.

During the war years, the manufacture of ice-cream was prohibited, but the ban has now been lifted. The product at present retailed has, in many cases, a lower fat content than was formerly the case, while cereal products have been extensively used to supplement the milk solids. Cereal solids will retain their popularity on account of their cheapness and, no doubt, many manufacturers will employ them until legislation prevents their further use. It should be emphasised that ice-cream may not contain the usual milk products at the present time although skimmed-milk powder may be used in the manufacture of present-day ice-cream. For sweetening purposes, glucose chips which have a sweetness value which is approximately three-quarters that of cane sugar are often used. The only materials allocated to the trade in common with pre-war ingredients are sugar and skimmed-milk powder.

Manufacturing Methods

As previously stated, ice-cream is manufactured in a variety of premises, the methods used varying according to the type of premises selected. The methods of manufacture may be grouped as follows:

(1) Home production.
(2) Small vendors.
(3) Large-scale manufacture.

(1) **Home Production.**—Ice-cream manufactured in the home is usually frozen custard or milk and cornflour frozen by one of the many types of home freezer now upon the market. As it is usually made in small quantities for early and private consumption only, the control of home-made ice-cream is relatively unimportant.

(2) **Small Vendors.**—It is interesting to note that the majority of outbreaks of infectious disease traceable to the consumption of ice-cream have arisen from the product manufactured by this class of vendor. This might have been expected when it is remembered that many small vendors are entirely ignorant of the simplest methods of sanitary food production,

while some are anything but conscientious or even scrupulous in the conduct of their business.

The mix generally used by such persons is as follows:

(a) Milk and cornflour with vanilla flavouring.

(b) Milk with ice-cream powder and flavouring.

(c) Custard, slightly flavoured but manufactured in larger quantities than is usual for home production.

Some small manufacturers use eggs, dried eggs or egg substitutes as a "filler." Some of the commoner ice-cream powders contain gum tragacanth or gelatine, finely ground sugar, and, quite often, cereal fillers.

The starchy ingredients are usually mixed into a smooth paste during preparation, with the addition of milk or other liquid, the whole being warmed. The flavouring matter and the sugar are added during this warming process, the mix being constantly stirred to prevent scorching. The whole is stirred until boiling-point is reached, and, after simmering for ten minutes, the mix is strained through a cheese cloth, being then allowed to stand overnight. As slow cooling favours bacterial development, this is a very unwise procedure, although it is general among small vendors who do not possess the necessary apparatus to provide rapid cooling of the mix.

When eggs are a constituent of the mix, the yolks are separated from the whites, and are then whisked and stirred-in after simmering has been completed. The whites are added the following day.

The mix is frozen on the following morning prior to delivery. A hand-operated freezer, which is usually rotated at a speed of 100 to 150 revolutions per minute, is used for this purpose. The speed of rotation, of course, depends upon the size of freezer employed. The freezing agent is usually a mixture of ice and salt. A common freezing mixture is made up from 10 lb. ice, 1 lb. salt, and 1 quart of water. The temperature of the resultant brine is in the neighbourhood of 21° F. In order to freeze 1 gallon of mix, approximately 28 lb. of ice and 6 lb. of salt will be required exclusive of ice needed for packing. The greater quantity of salt employed, the quicker the ice will melt. Once the freezing operations are commenced, they should not cease until the ice-cream has attained the required consistency. Very rapid freezing is not desirable with such apparatus, and when rotation of the freezer becomes difficult, operations should cease, otherwise there will be a loss of overrun owing to the contained air being worked out.

This method of manufacture affords countless opportunities for bacterial contamination, although excellent ice-cream can be made in this way provided care in handling is exercised. The milk used may possess a very high bacterial content, while the absence of any pasteurisation of the mix will assist in the rapid development of such organisms as the original product may have contained. Low-grade or cheap materials may be used in its manufacture and may also form a potent source of contamination, while annatto is often employed to enrich the colour of the mix. The utensils used in the preparation of the ice-cream often comprise an additional and fertile field of danger. Dirty pans and other utensils, inefficiently washed, unsterilised and stored in all manner of unsatisfactory quarters, are often to be found. The domestic washing copper is sometimes used for the preparation of the mix, the product in such cases being almost invariably

allowed to cool in uncovered containers on the kitchen sink, open to atmospheric and other incidental pollution. Reference has already been made to the unsatisfactory storage of cans and freezers. With this type of person manufacturing ice-cream, there is little wonder that the product has been the source of many disease epidemics. It should be stated, however, that such carelessness, although by no means unusual, is not universal among small vendors, and that large manufacturers cannot be entirely absolved from blame.

Among some small-scale manufacturers, the ice-cream mix is poured over a revolving drum which contains the freezing mixture. The mix is frozen and is removed by a metal scraper somewhat similar to the removal of roller-dried milk. The frozen material falls direct into a container. Difficulties in cleansing require to be overcome and many high bacterial counts in this class of ice-cream are due to difficulties in this respect. The movable parts of the apparatus can be easily removed for cleansing and sterilisation, but difficulty is likely to be experienced in sterilising the fixed cylinder. The makers of this type of apparatus recommend that boiling detergent solution should be used to cleanse the fixed cylinder, but this may entail difficulties as regards solution temperatures.

(3) **Large-scale Manufacture.**—When substantial quantities of ice-cream are to be produced, manufacturing methods are generally more hygienic and satisfactory. The manufacturer who wishes to maintain a large output has to make a heavy capital outlay on the provision of suitable premises and plant, and in doing so he is naturally careful to ensure that his buildings and machinery are in every way suitable for the purpose. Typical mixes have already been given, and it now only remains to describe the various processes which the mix must undergo before it can be retailed to the public as ice-cream. The points requiring special mention are:

(a) Premises.
(b) Plant.
(c) Raw materials.
(d) Mixing.
(e) Pasteurisation.
(f) Homogenisation.
(g) Cooling.
(h) Ageing.
(i) Freezing.
(j) Hardening.
(k) Packing.

(a) *Premises.*—As with other foodstuffs, premises used for the manufacture of ice-cream should be thoroughly hygienic and should be maintained in a satisfactory sanitary condition. The common faults to be found in premises where ice-cream is prepared are:

(i) *Lack of Sufficient Light.*—This not only affects the health of the workers but tends to prevent the premises being maintained in a scrupulously clean condition, since dirt cannot easily be seen.

(ii) *Lack of Sufficient Ventilation.*—This again reacts upon the health of the workers and prevents steam and odours escaping from the processing rooms.

(iii) *Lack of Suitable Storage Accommodation for Raw Materials.*—It is important that the raw materials should be protected from contamination.

(iv) *Lack of Storage for Waste Products.*—This is an essential point which is unfortunately often overlooked.

(v) *Inadequate Water Supply.*—This prevents the thorough cleansing of the plant, utensils, and the washing of the employees' hands.

The proper layout and construction of premises should be considered when the building is first planned. It is particularly important that the premises should be so arranged that cleanliness is assured. In consequence of this, sufficient space should be provided between all the machinery essential for production, and no corners where debris can accumulate should be allowed. The machinery must, of necessity, be installed in such a position as will allow of its most efficient use, but means of easy cleansing and inspection must also be afforded.
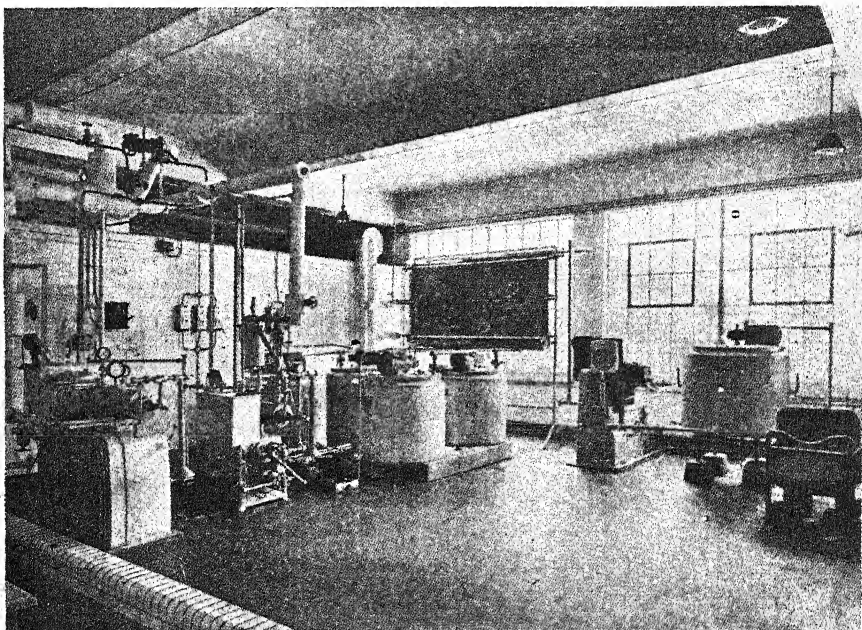
By courtesy of Cherry-Burrell, Ltd.

Fig. 1—General view of Ice-cream Plant illustrating entire processing from Milk Receiving Tank to Freezer

Certain points in construction require particular attention. The *walls and ceilings* should be constructed of *smooth, hard, and non-absorbent materials* and should be free from crevices or angle joints. *Glazed bricks or tiles* are very desirable for wall surfaces. *Floors* should be constructed of *tiles or concrete. Wooden floors* are often found, and, while hardwood may be fairly suitable in some respects, such floors should not be countenanced for the following reasons:

(i) The crevices between the boards allow dirt to accumulate.

(ii) The boards are easily indented, rendering the removal of all dirt difficult.

(iii) Constant washing and scrubbing renders the wood soft, while the material holds a considerable quantity of moisture.

Tiled floors are eminently suitable, as they are hard-wearing, while defective sections can easily be renewed. They also possess the advantage of revealing

any lack of cleanliness at a glance. Tiles used for flooring should be hard, and should not possess an exceedingly smooth surface, as in such cases they may be dangerous to the feet. *Concrete* finished off with a non-slip surface is quite suitable. All *angles* between walls and floors should be rounded off and floors should be laid with a sufficient *fall* for drainage purposes.

Sufficient drainage must be provided by means of *trapped gullies* situated outside the building and connected to drains of adequate size. *Drainage gullies* covered with removable iron gratings should be provided to carry off waste water from the floors. Sufficient external area should always be left round the building. The *fittings* should receive special attention. *Shelves* should be fitted on stands away from the walls or fixed to the walls by means of iron brackets. Metal racks are preferable to wooden shelves, but the latter may be permitted if they are easily removable for cleansing purposes. Plugging of the walls should be avoided wherever possible, as openings made in the walls provide harbourage for dirt and insects. *Tables*, when required, should be provided with impervious tops to facilitate cleansing. Wooden-topped tables should never be used, as wood absorbs moisture and can never be rendered sterile, however much it is scrubbed.

Ventilation is very important and should be sufficient to remove any steam or other odours from the premises. Moist, damp air encourages the growth of moulds and fungi. The various rooms should also be provided with sufficient means of *natural and artificial light*. Rubbish should be removed from the buildings to the exterior of the premises at least once daily. *Containers* should be disinfected after they have been emptied.

Any official making an inspection of the premises should note the condition of the walls, floors, fittings, and the efficiency or otherwise of the lighting and ventilation. The condition of the plant should also be noted, and the methods of cleansing and sterilisation carefully inspected. Rinse samples from all surfaces should occasionally be taken for bacteriological examination.

(b) *Plant.*—While it is a fact that the complete plant required by the small vendor for the manufacture of ice-cream is a small container fitted with a stirring gear, and suspended in a tub of ice and salt, it is also a fact that to-day, a dozen or more complicated machines may be required for each of the separate stages of manufacture. The design, manufacture, and installation of modern plant (see Figs. 1 and 2) occupy the attention of engineering specialists. Designs and methods of manufacture change rapidly. As a result of such changes, it is possible to obtain a purer and smoother-textured product than ever before, by more economical methods.

The plant required depends upon the daily output desired, the apparatus naturally varying according to whether a small, medium, or large output is to be produced. Ice-cream factories in this country can produce anything from 200 to 20,000 gallons per day. The arrangement of the plant in the factory is also important. Quick handling of the frozen unhardened cream is essential, and the processes should be arranged in sequences. The pasteurising, homogenising, and cooling equipment should be arranged on one level. The ageing vats should be fixed at a higher level, with the freezers underneath. The hardening rooms may be situated at ground level, or, if a hopper system of discharge from the freezers is in operation, the packing and hardening rooms may be arranged on a floor below.

All plant should comply with the following conditions:

(i) Should be constructed in such a manner as to facilitate cleansing and sterilisation.
(ii) Should be easy to dismantle and assemble, and be sufficiently strong to withstand considerable usage.
(iii) Should be designed to give a product of uniform quality.
(iv) Should be simple and reliable in operation.
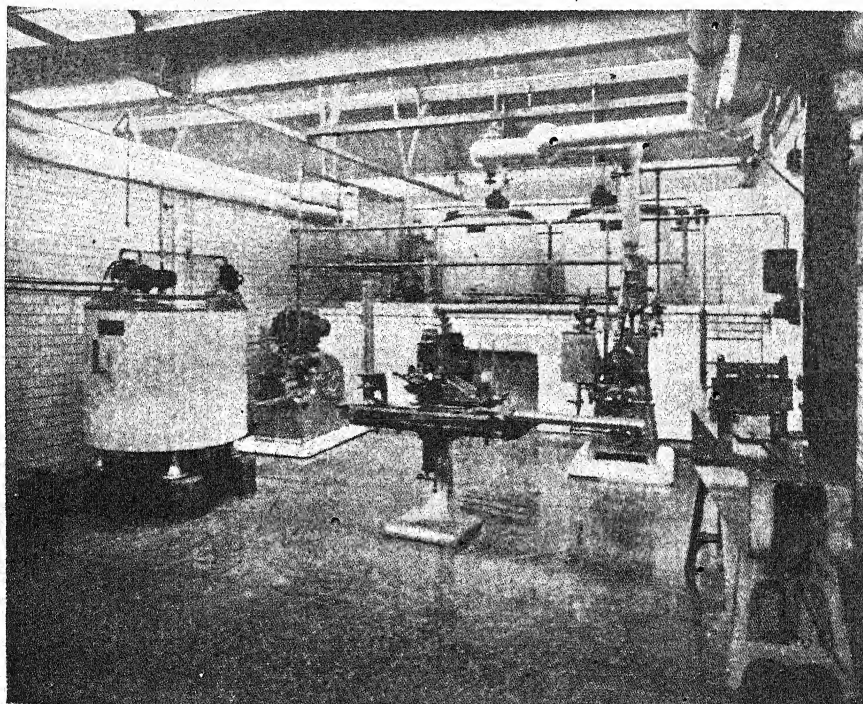
By courtesy of Cherry-Burrell, Ltd.

FIG. 2—General view of Ice-cream Plant showing Cup Filling and Brick Cutting Machines in foreground

Machines such as motors should be adequately protected from dust and dirt, and care should be taken in designing plant to ensure that the product cannot be contaminated by the machinery used. Glands and stuffing boxes in contact with the product should be viewed with suspicion and should be avoided wherever possible.

Pumps may be necessary for the transference of the mix through all its manufacturing stages, although, in a well-planned factory, the need for pumping will be minimised. Three types of pump are used for this purpose:

(i) *Plunger Pumps*.—These are reliable but difficult to cleanse. They may also exert a detrimental effect upon the quality of the finished article.
(ii) *Centrifugal Pumps*.—These operate at high speed and are reliable yet simple in construction. Cleansing is remarkably easy. This type of pump cannot be used for suction.
(iii) *Rotary Pumps*.—This type of pump is largely employed in dairy work, particularly in pasteurisation plants. It is easy to dismantle, cleanse, and reassemble.

All equipment used for the manufacture of ice-cream must be constructed of such material as will not be acted upon chemically by the product. If this cannot obtain, the vessels should be lined with such material. The principal metals used in the construction of ice-cream equipment are tinned copper, tinned gunmetal, tinned steel, aluminium, nickel, monel metal, and glass-lined steel. The material chosen should be one which is not likely to corrode, since this increases the risk of contamination and also renders cleansing difficult. When the question of heat transference is considered, copper is by far the most satisfactory, although aluminium and stainless steel are also adequate. Glass-lined steel is not so valuable in this respect, although, from a hygienic point of view, it is ideal. It possesses the disadvantage of great weight, while the presence of minute air bubbles within the glass surface may allow it to become a source of bacterial contamination.

When the apparatus is constructed of copper, steel, or gunmetal, it is essential that such surfaces should be heavily tinned. If this is not done, these surfaces are liable to impart unpleasant odours and flavours to the product. Aluminium is generally satisfactory, being frequently used for tanks and vats. Stainless steel, though expensive, is satisfactory. It is easily cleansed, possesses a long working life, and can be constructed with extremely smooth surfaces.

Pipe-lines are exceedingly important. They should be constructed in sections, so that they may be easily dismantled for brushing and cleansing. They should be provided with steam points for sterilisation purposes.

When plant is installed, means of *sterilisation* must not be overlooked and the necessary provision made in order to ensure that the plant may be efficiently sterilised after cleansing has been completed.

The *refrigerating machinery* is an important part of an ice-cream production plant. Refrigeration involves:

(i) Cooling the mix after pasteurisation.
(ii) Maintenance of the ageing temperature.
(iii) Freezing the mix after ageing.
(iv) Hardening the ice-cream.
(v) Maintenance of a constant low temperature in the hardening room.

A compressor must be selected to deal with all these duties, and should be capable of constant work. The size of such compressor will depend upon the quantity of ice-cream to be produced during each working day.

The operation of the plant is important. However satisfactory the plant may be, it is necessary that it should be operated in a scientific manner, if good results and a uniform product are to be expected and maintained. The essentials of satisfactory plant operation are:

(i) Suitable appliances.
(ii) The maintenance of essential temperatures.
(iii) Speed of mixing.
(iv) Scientific control.
(v) Efficient cleansing and sterilisation.

(c) *Raw Materials*.—For reasons already indicated, good-quality materials are essential if the resultant manufactured article is to be satisfactory in all respects.

The ingredients of a quality ice-cream are sweet cream, sweet milk, fresh butter, unsweetened condensed and evaporated milks, full-cream milk

powder or separated milk powder, eggs, cane sugar, and flavours of various
natures.   The use of dried eggs in the manufacture of ice-cream is now
permissible under licence and an allocation is obtainable from the Ministry
of Food.   The employment of this substance is controlled by the Dried
Eggs (Control of Use) Order, 1945.   The licence states that:

(a) After the product is mixed with liquid it shall not be kept for more
than one hour at any temperature between 45° and 150° F. before it is
subjected to heat treatment.

(b) It shall be heat treated at a temperature of not less than 150° F. for
thirty minutes, or alternatively to not less than 160° F. for ten minutes.

(c) The product shall then be reduced to a temperature of 45° F. or less
within one and a half hours and shall be kept at such temperature until it is
frozen in the course of manufacture of the ice-cream

Gelatine is used to impart consistency and, being a non-crystallisable
substance, prevents the crystalloids in the mix, i.e. milk, sugar, and water,
from separating in the form of crystals.   Sodium alginate may also be used
as a stabiliser.   Glucose and dextrose are often used by ice-cream manu-
facturers in place of cane sugar.

The materials and ingredients which require to be stored should be
kept in suitable covered containers, which should in turn be housed in a
separate storeroom from which they are issued as required.   The storeroom
should be maintained in a thoroughly clean and sanitary condition.

(d) *Mixing*.—The operations of mixing and pasteurisation are usually
carried out in the same vessel.   It is essential that the mixing be carried
through in a speedy manner in order to ensure a good-quality product,
while the mix should be properly balanced, otherwise a poor quality article
will result.   The ingredients should be accurately weighed or measured.
When the mix has been calculated or weighed, the liquid ingredients should
be placed in the mixing vat followed by the solid materials.   When the
vat contains sufficient liquid, heat may be applied.   Milk powder should
be sifted on to the contents of the vat with the agitator in operation, but
if a coil vat is employed, the powder should be added on the side where the
coil turns down into the vat.   Gelatine is often added prior to heating,
being mixed dry with sugar or added separately in powder form.   Sugar
is usually added when the temperature is between 110° and 120° F., and it
will readily go into solution.   The addition of sugar after processing is
sometimes practised and this method has been found to give a less viscous
mix and a better whipping product which will not melt so readily at normal
room temperatures.   If sweetened condensed milk is a constituent of the
mix, allowance must be made for the sugar it contains.   The utensils,
stirrers, etc., used should always be maintained in a cleanly condition and,
following cleansing and sterilisation, should be stored in a satisfactory
manner.   The mix must not be retained at temperatures between 45° and
150° F., before being subjected to heat treatment in accordance with the
methods outlined on page 68.

Since the war terminated and permission to manufacture ice-cream
has again been given, there has been an extremely large increase in the
employment of a *cold mix* owing, no doubt, to the ease with which the mixture
is prepared and to the introduction, prior to the war, of electrically-operated
counter freezers.   As the only liquid milk which may be added is that
which is surplus to requirements and which by the reason of its staleness

must possess a high bacterial content, ice-cream of this nature is likely to contain an incredible number of organisms. After the ingredients have been thoroughly mixed, the whole is frozen and sold almost immediately. The bacterial content will be further increased if any delay occurs between mixing and freezing. Many cold mixes have been found to contain extremely low milk-fat and total solids contents and while no standard for ice-cream exists in this country at the present time, which in itself is regrettable from the trade point of view, many ice-creams are entirely deficient in food value when prepared in this manner. From the public health viewpoint, the matter is more serious. Raw milk is capable of carrying disease-producing organisms, and many outbreaks of disease have occurred through its consumption.

Under the terms of the Ice-Cream (Heat Treatment) Regulations, 1947, the only cold mix powder which may be used is one which has been produced by evaporating a liquid mixture which has already received heat treatment in accordance with the methods outlined on page 68. In addition, the mixture, when reconstituted with water, shall be converted into ice-cream within one hour of such reconstitution.

(e) *Pasteurisation.*—The pasteurisation of the mix is a particularly important operation in order to dissolve the sugar and gelatine, to prepare the mix for homogenisation and, most important of all, to destroy any harmful bacteria which may be present. From a public health point of view, this process is extremely important, and it is essential that the greatest care should be taken to ensure efficient processing.

It should be remembered that the pasteurisation of ice-cream mix is much more difficult to carry out than is the similar treatment of milk. The mix is thicker and more viscous; it is extremely difficult to obtain an even heat throughout the batch and there is much more chance for some of the material to escape adequate heating. In addition, the transference of heat is slow and not so uniform as is the case with milk. Further, hot spots and overheating are likely to occur with the result that burnt flavours may be present in the final product. From a public health point of view, however, the main risk lies in underheating, and pasteurisation, if not properly carried out, is just a waste of time and money.

Pasteurisation in plants of small output is carried out in holders very similar in type to those used for the "batch" pasteurisation of milk. These machines are usually constructed of stainless steel, the inner vessel, in which the mix is held, being surrounded by a jacket, in which the heating agent may be either steam or hot water. The mix is held in this vessel for a period of thirty minutes at not less than 150° F. Somewhat higher temperatures of not less than 160° F. for ten minutes are also used, but if the mix is heated to an excessively high degree for too lengthy a period an objectionable cooked flavour may result.

Most plant manufacturers prefer to use hot water as the heating agent, being of the opinion that, if steam is used, a burnt flavour may be imparted to the product. The holder requires to be insulated during the holding period as a means of heat maintenance, this being generally provided for, either by the use of insulating materials or by the creation of a vacuum in the space between the inner and outer jackets of the apparatus.

In choosing a pasteuriser, the following essentials should be borne in mind:

  (i) Efficient methods of insulation to ensure correct heat maintenance.

  (ii) Ease of cleansing following treatment of the mix.

  (iii) Absence of "dead ends" or "cold pockets" to ensure adequate holding of the mix at the correct temperature.

  (iv) Absence of undue foaming during operation (it is also most important that all foam present should be held at the correct temperature).

  (v) Provision of an accurate temperature recorder *and* an indicating thermometer.

  (vi) Absence of contact between the glands and stuffing-boxes, if present, and the mix.
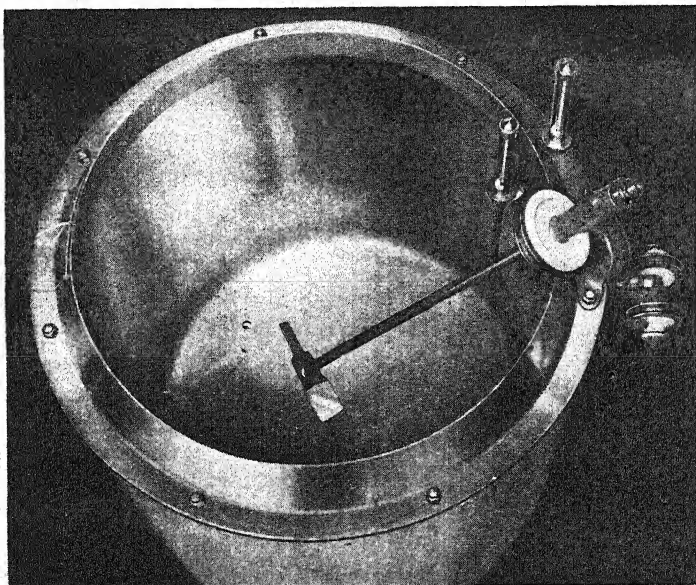
By courtesy of the Aluminium Plant and Vessel Company, Ltd.

FIG. 3—Ice-cream Mix Pasteuriser (Overhead View)

It is essential that a suitable *agitator* should be provided, to ensure that no particles of sugar or other solids may remain undissolved, and also in order that the entire mix may be distributed evenly throughout the batch and under- or over-heating prevented. In some types of holder, agitation is provided by additional blades fixed to the inner walls of the holder, but, whenever possible, the agitator should be placed as close as practicable to the base of the vessel.

Fig. 3 illustrates the "A.P.V." mixer-pasteuriser for small outputs. The inner vessel is of stainless steel and is surrounded by a hot-water jacket, the water being heated by steam through a silent heater. An agitator or paddle is provided to ensure uniformity in the mix and to give a uniform heating. A recording thermometer is fitted.

The "Cherry-Burrell" ice-cream mixer and pasteuriser shown in Fig. 4 is yet another useful type. The machine is constructed of stainless steel, insulated and jacketed. It is heated rapidly by means of hot water. A vertical two-propeller agitator is fitted, one blade being fixed close to the base of the vessel and a further blade mounted at the centre. The agitator is quickly removed for cleansing. This apparatus is simple to operate and economical in use.

When large outputs are required, the comparatively small heating surfaces of
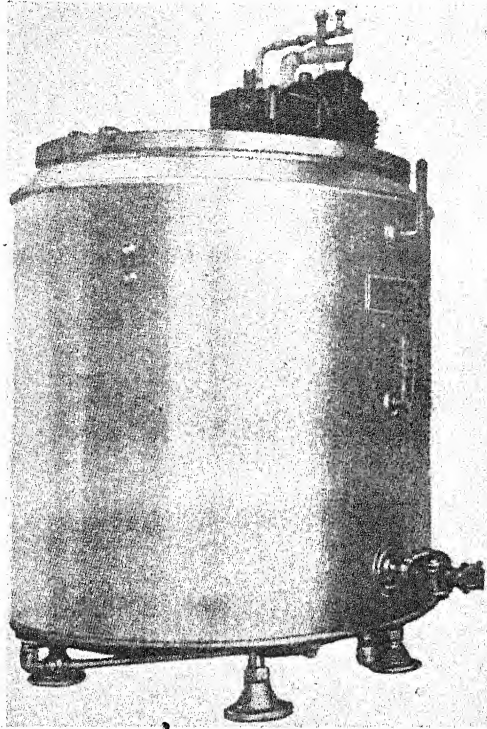
By courtesy of Cherry-Burrell, Ltd.

FIG. 4—Batch Pasteuriser for small Ice-cream Factory
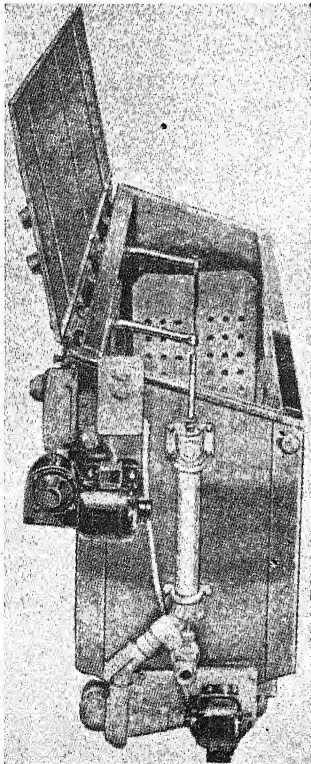
By courtesy of Cherry-Burrell, Lt.d

FIG. 5—Batch Pasteuriser for larger Outputs

the types specified above render the time required for processing unduly long, and a different type of apparatus is called for. In such cases, the horizontal coil machine is adequate. This type of machine consists of a semi-cylindrical trough into which the mix is placed. A coil, which revolves on a horizontal axis, passes through the trough from end to end. The rotation of the coil induces circulation and also provides suitable agitation for the ingredients. Hot water is circulated through the outer jacket. Glands are necessary at each end of the coil, although some makers prefer the flow and return to take place through concentric pipes placed at one extremity of the machine. This procedure reduces the risk of contamination. In some instances, blades are fitted to the coils in order to assist in the mixing of the solid ingredients.

The apparatus illustrated in Fig. 5 is an extremely efficient plant for dealing with larger outputs.

The pasteurisation of ice-cream mixes under vacuum in a similar manner to cream (see page 91) has been successfully carried out in the United States of America.

(*f*) *Homogenisation.*—Following pasteurisation, the mix is homogenised. The pressure used varies between 2,500 and 3,500 lb. per square inch, according to the composition of the mix. This process is necessary for the following reasons:

(i) To break up all the butter-fat globules.
(ii) To distribute the particles of fat evenly throughout the mass forming a permanent fat emulsion.
(iii) To ensure the smooth texture of the finished article.
(iv) To reduce the ageing period normally required for the mix.
(v) To improve the whipping qualities of the mix and ensure a higher overrun in the freezer.

The viscosity of the mix can be increased by the addition of more non-fatty solids, e.g. sugar or gelatine. If the mix is pasteurised and homogenised at low temperatures with high pressure, and if the ageing period is lengthened viscosity will be increased. Agitation of the mix in the ageing vat will, if excessive, decrease viscosity, as will also pasteurisation and homogenisation at high temperatures with low pressure. Viscosity is important since it exerts a considerable influence upon the smoothness and palatability of the finished article.
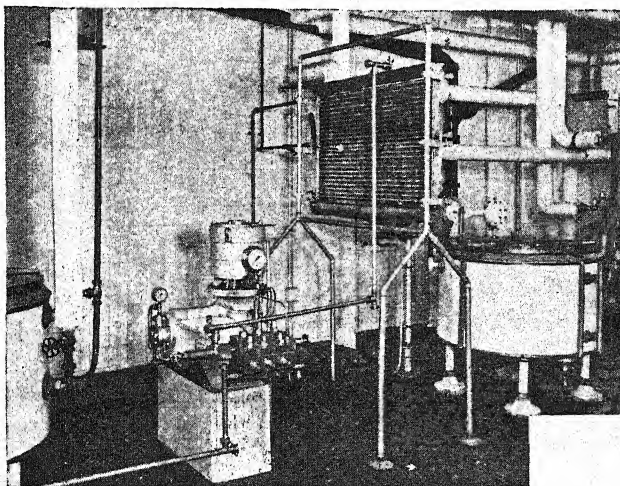
By courtesy of G. & J. Weir, Ltd.
FIG. 6—Ice-cream Plant, showing Homogeniser

It is, however, usual to homogenise the mix, a process which is essential in order to obtain uniformity and increased viscosity in the mix. This is readily controlled by regulating the pressure and the temperature. The temperature of homogenisation is generally slightly lower than that of pasteurisation, although it may vary between 140° and 165° F. A more viscous mix can be secured by lowering the homogenisation temperature or by increasing the pressure, and by the correct manipulation of these two conditions mix viscosity can be accurately controlled. When dealing with war-time mixes, higher pressures and temperatures may be usefully employed. By means of such an apparatus, the mix is transformed into a completely homogeneous mass, the butter globules being reduced to approximately one-sixth of their original size   The remaining solids are atomised

and held in suspension, thus preventing their further separation. The breaking up and complete homogenisation of the butter-fat, and the atomisation of the other constituents of the mix, give a greatly improved product of thoroughly even consistency, smoother in body and richer in flavour. Homogenisation provides another important benefit. It enables the manufacturer to minimise any danger of churning the butter-fat contained in the mix during freezing operations.
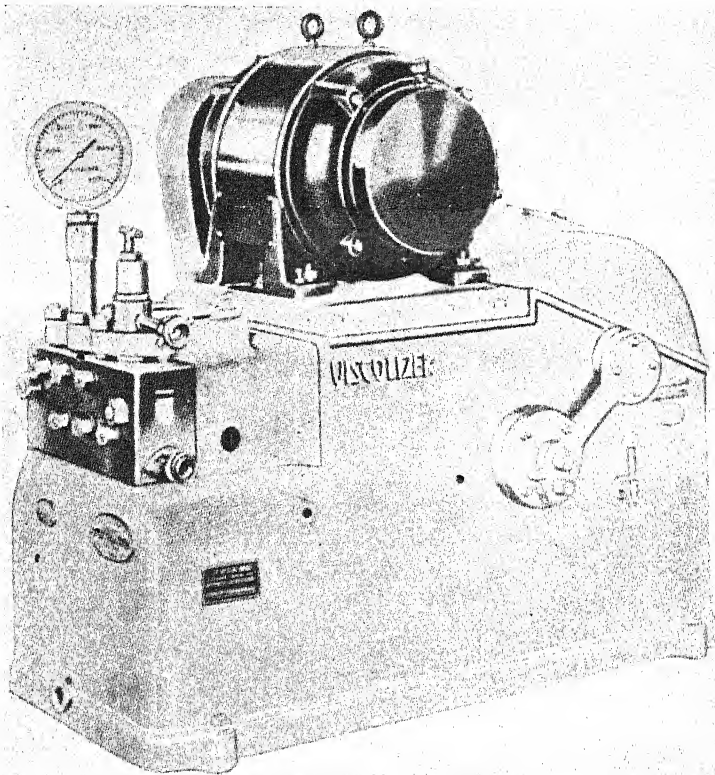
By courtesy of Cherry-Burrell, Ltd.

FIG. 7—Viscoliser

During homogenisation, the mix is drawn from the pasteuriser while still hot and forced at high pressure (3,500 lb. per sq. inch) through a small orifice or between the faces of a valve by a pump, after which it is sprayed in a closed chamber. The valve is constructed of agate, stellite, or stainless steel, and is held against its seat by a strong spring, the tension of which may be varied to suit existing conditions. Two-stage homogenisation is sometimes used to prevent clump formation of fat and to procure a better whipping mix, but this is not a widely adopted practice in this country, although it is quite usual in the United States of America. A new type of valve, which depends upon the stretch of a metal sleeve to produce the necessary orifice, has recently been patented. A tensioned spring is not required with this method, while a greater efficiency in emulsification is obtained at a lower pressure and with reduced power consumption.

If the pressure is too low, the fat will not be completely emulsified and the whipping of the article will be affected as will the body of the resultant product. Too high pressures result in excessive viscosity and more time to whip to the desired overrun is required. While increased pressures produce a smoother textured and more resistant ice-cream, a dry, waxy consistency may result.

The food contacts in homogenising apparatus should be constructed of stainless steel, and precautions must be taken to ensure that there is no leakage by the pistons. The homogeniser should always be cleansed and sterilised immediately after use. It is important also that the gauges provided on the apparatus should be frequently checked, otherwise ineffective homogenisation with consequent loss of texture in the final product will result.

Fig. 6 illustrates the "Weir" homogeniser as used in conjunction with an ice-cream plant. The apparatus is eminently suitable for its purpose, all parts coming into contact with the mix being constructed of acid-resisting stainless materials. The piping is designed to afford accessibility for cleansing purposes. There are no plunger packings to contaminate the product.

The "Cherry-Burrell" ice-cream mix viscoliser illustrated in Fig. 7 is an exceedingly strong machine, all parts being easily accessible for cleansing purposes. The viscoliser is totally enclosed and the Duo-Visco valve is constructed of stainless steel.

Microscopic examination of the mix should be regularly carried out to check the effectiveness of homogenisation.

(g) *Cooling.*—After the mix has been homogenised, it is necessary to reduce its temperature rapidly to the level at which it is aged, i.e. 34° to 40° F. in order to prevent bacterial action. Under the terms of the Ice-Cream (Heat Treatment) Regulations, 1947, the mix must be reduced to a temperature of not more than 45° F. within 1½ hours and must be maintained at such temperature until it is frozen. Mixes containing gelatine will develop less viscosity when cooled rapidly from the pasteurisation temperature down to 40° F. than when cooled rapidly to 70° F. and slowly to 40° F. Less gel formation occurs when the mix is cooled rapidly to 40° F. or lower and if this procedure is carried out increased quantities of gelatine must be used.

Cooling is effected by various types of apparatus, among which the following may be mentioned:

    (i) Tubular surface cooler.
    (ii) Enclosed tubular cooler.
    (iii) Plate heat-exchanger cooler.

The cooling medium may be chilled water, water in conjunction with brine, or water in conjunction with the direct expansion of ammonia.

(i) TUBULAR SURFACE COOLER.—This type of apparatus is in fairly common use but possesses several disadvantages. A large space is required for installation purposes because of its size. There is also a certain loss through evaporation, while freezing of the mix on the lower portion of the cooler may occur, generally through bad management. The efficiency of the cooler is decreased if the mix is allowed to freeze on to its surface, and the desired low temperature may not be maintained. It should be remembered that mix after pasteurisation has lost a considerable portion of its

initial bacterial content and is therefore extremely liable to recontamination if not carefully handled. Surface-type coolers, unless provided with some means of protection, afford opportunities for air-borne contamination of the mix. If such a cooler is used, it is essential that some means of protection should be afforded to the material passing over it. For this reason, it is usual to provide a well-fitting metal shield to afford protection from dust and dirt. One advantage claimed for the open-type cooler is the fact that the mix is thoroughly aerated during its passage over the apparatus, while any objectionable gases which it contains may be liberated. To allow of aeration without the risk of air-borne contamination, a new type of "surface" cooler has been devised. This apparatus is enclosed in a glass case to which a supply of purified air has access.

The cooler is divided into two sections, primary cooling being carried out in the upper section by means of water, this being followed by a secondary cooling by brine or chilled water.

The water section of the cooler should be so balanced that the temperature of the mix is reduced to approximately 75° F., after which it is further reduced to 34° to 40° F. by means of brine or other method of refrigeration. A cooler of this type should be designed to allow a thin film of mix to pass over, in order to ensure that the interchange of heat is completely uniform and that the heat is extracted from the mix in an economic manner and within correct temperature limits.

(ii) ENCLOSED TUBULAR COOLER.—When this type of cooler is used, the mix is passed in a thin film through an annular space between an inner and outer tube, while the cooling agent flows through the inner tube. While the use of this apparatus prevents the risk of any air-borne contamination, cleansing is difficult and an appreciable amount of space is required for installation purposes, as the tubes have to be withdrawn while they are cleansed. This type of cooler is not in common use for the cooling of ice-cream mixes.

(iii) PLATE HEAT-EXCHANGER COOLER.—This type of apparatus is becoming increasingly popular, possessing as it does decided advantages over the other types already described. The apparatus, illustrated in Fig. 8, consists of a series of plates (see Fig. 9), which are held together in a frame. These plates are either grooved or provided with "knobs." The mix flows in a vertical direction along the grooves formed on one side of the plate, the cooling agent flowing along the reverse side. This apparatus may be quickly opened up for cleansing and inspection and may be sterilised by hot

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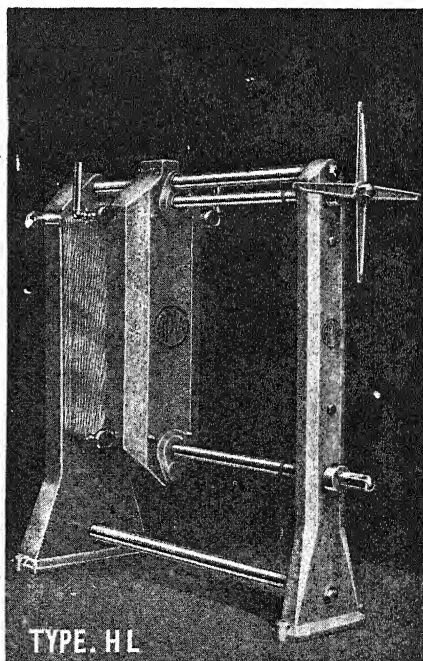
By courtesy of the Aluminium Plant and Vessel Company, Ltd

FIG. 8—Modern Heat-exchanger
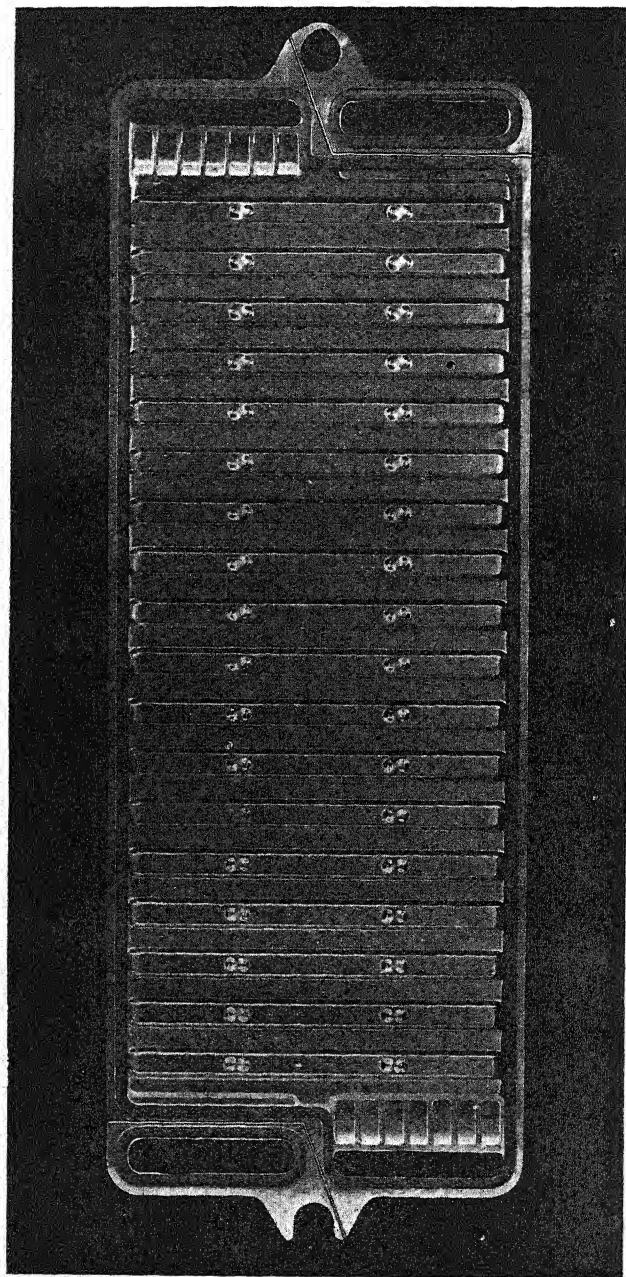
By courtesy of the Aluminium Plant and Vessel Company, Ltd.
FIG. 9—Heat-exchanger Plate

water and steam in a closed position. It possesses an added advantage
inasmuch as the mix, during the reduction of its temperature from 140°
to 40° F. or below, i.e. when it is most sensitive to air-borne contamin-
ation, remains in a hermetically-sealed circuit. The plate type of cooler
gives increased cooling efficiency and occupies very little space, while there
are no losses through evaporation or spillage. By the use of brine at a

temperature of 25° to 30° F., it is possible with this type of cooler to cool the product to as low as 35° F. with ease.

Whichever type of cooler is used, its capacity must be sufficient to cope with the output of the homogeniser.

(*h*) *Ageing*.—The use of the term "ageing" may sound extremely paradoxical, especially when it is remembered that ice-cream is a perishable article. Ageing, however, is essential because of the beneficial effects it has upon the whipping of the mix and the body of the ice-cream and in order to obtain rapid freezing. The mix is held in what is known as the "ageing vat" for twelve to twenty-four hours at 34° to 40° F. before freezing takes place. This period is particularly necessary with war-time mixes which possess a lower solids content than was formerly the case. The process increases both the acidity and the viscosity of the mix, although it has been stated that practically all the benefits derived from this process have taken place within two to four hours after the product has entered the ageing vat, particularly if a gelatine mix is employed. With sodium alginate the increase in viscosity takes place

By courtesy of Cherry-Burrell, Ltd.
FIG. 10—Upright Ageing Vat

almost immediately the mix is cooled so that ageing assumes much less importance. The increase in acidity is slight if the mix is aged at a temperature below 40° F. and for a period not exceeding forty-two hours. It is probable that the gelatine, or other stabiliser, which is almost invariably added to the mix, exerts more influence in increasing viscosity than does the acidity. This acidity, which is due to the formation of lactic acid in the mix, should not greatly exceed 0·2 per cent. If, on the other hand, the acidity is below 0·1 per cent., a soapy taste will result.

It has become common practice to use rennet in the manufacture of ice-cream. Rennet considerably accelerates the ripening process, while the mix is smoother and the resultant product possesses a better overrun. The quantity of rennet added depends upon the temperature of the mix, but approximately one-third to two-thirds of an ounce are commonly used with each 100 lb. of mix. The use of rennet also possesses a further advantage in that considerably less stabiliser is required when this substance is employed.

Ageing vats are of varying types. The simplest is a plain circular tank insulated with cork (see Fig. 10). By the provision of an outer shell, brine

FIG. 11—Horizontal Ageing Tank

may be circulated in the annular space. The horizontal types illustrated in Figs. 11 and 12 are similar in many respects to a horizontal mixer and pasteuriser. The tanks are insulated on all sides, gentle agitation being provided. Violent agitation will disturb the viscosity of the mix. An ageing vat of recent design has cooling coils carried in a central rotating drum, at the lower end of which are attached fins or blades to provide agitation. Direct-expansion cooling may be used and, as the refrigerant is completely immersed in the product, great efficiency is thus obtainable.

The number of ageing vats required varies according to the quantity of mix to be treated. They should be constructed of stainless or glass-lined steel, and vary in capacity from 50 to 3,000 gallons.

In order to control the product which is being manufactured, each batch of mix, prior to ageing, should be checked for fat, total solids, acidity and bacterial content. This practice is extremely useful as loss through excess fat or total solids is prevented and assistance is afforded in establishing a uniform quality.

(*i*) *Freezing.*—Commercially, both batch and continuous freezers are employed, the freezing agent being either brine or direct gas expansion. The former type uses a brine jacket for refrigeration purposes, while the latter possesses a cooling jacket in which a liquid refrigerant such as ammonia is directly evaporated. A freezer has three functions, viz.:

(*a*) To cool the mix to a low temperature so that the product may be hardened.

(*b*) To incorporate a predetermined amount of air into the mix to provide a proper swell or overrun.

(*c*) To mix flavours, fruit, etc., into the mix as it is being frozen.

The number of freezers required will be decided by the daily output of the
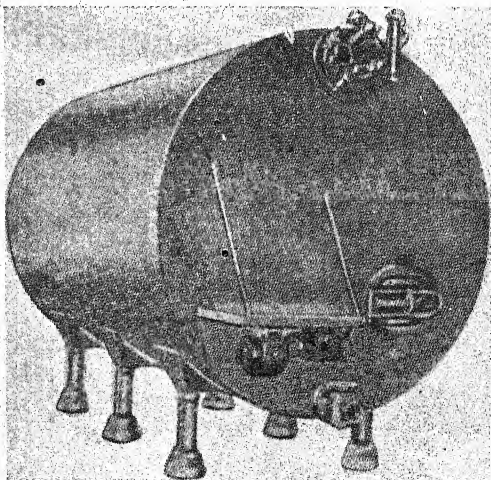
FIG. 12—Horizontal Circular Ageing Tank

plant, and great care is necessary in the choice of such apparatus. The mix is worked to the desired consistency in the freezer, air being incorporated to give an overrun of 80 to 90 per cent. by volume. During the freezing process, the mixture begins to increase in volume from 34° F. down to 29° F. The temperature at this point remains stationary for some time, owing to the latent heat of freezing. Design and construction are important factors affecting overrun, and it has been proved by experiment that the desired overrun is more easily obtained by means of a horizontal freezer. Horizontal freezers also provide the greatest degree of whipping surface.

The prime essentials of a satisfactory freezer are :

(i) Ability to freeze quickly.
(ii) Possession of dashers so designed as to ensure a rapidly obtained overrun.
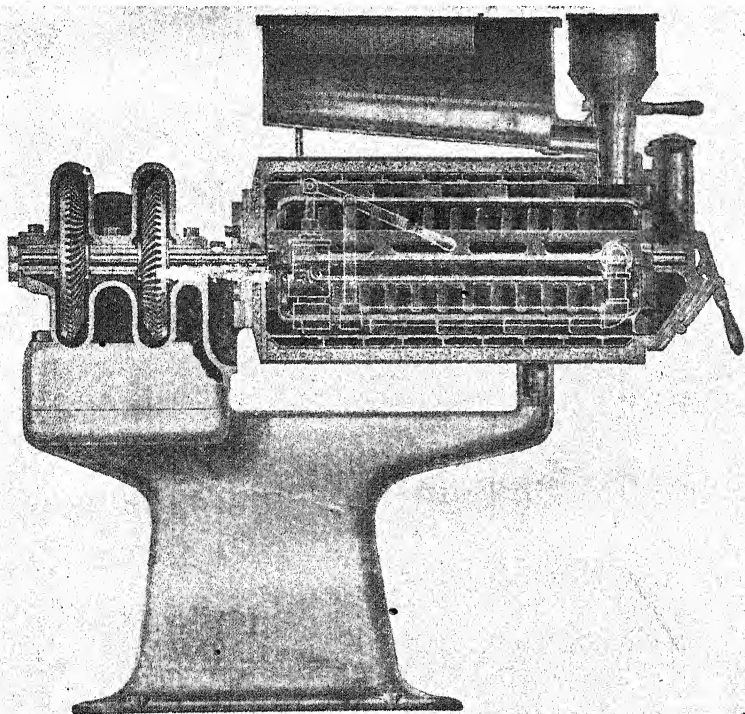
By courtesy of the Creamery Package Mfg. Co. Ltd.

FIG. 13—Fort Atkinson Horizontal Freezer (Section)

The type of refrigerating agent used also exerts an influence upon the speed of freezing. As mentioned above, brine or the direct expansion of gas may be used, present-day manufacturers favouring the latter method. Direct-expansion freezers have been found in practice to give a more speedy freezing, with a consequent acceleration of production and an enhanced quality. Such freezers require to be fitted with an automatic control in order that flooded conditions in the cylinder and reservoir may be maintained. The freezer drive is important, direct drive being preferable. This prevents any loss in revolutions and maintains constant speed.
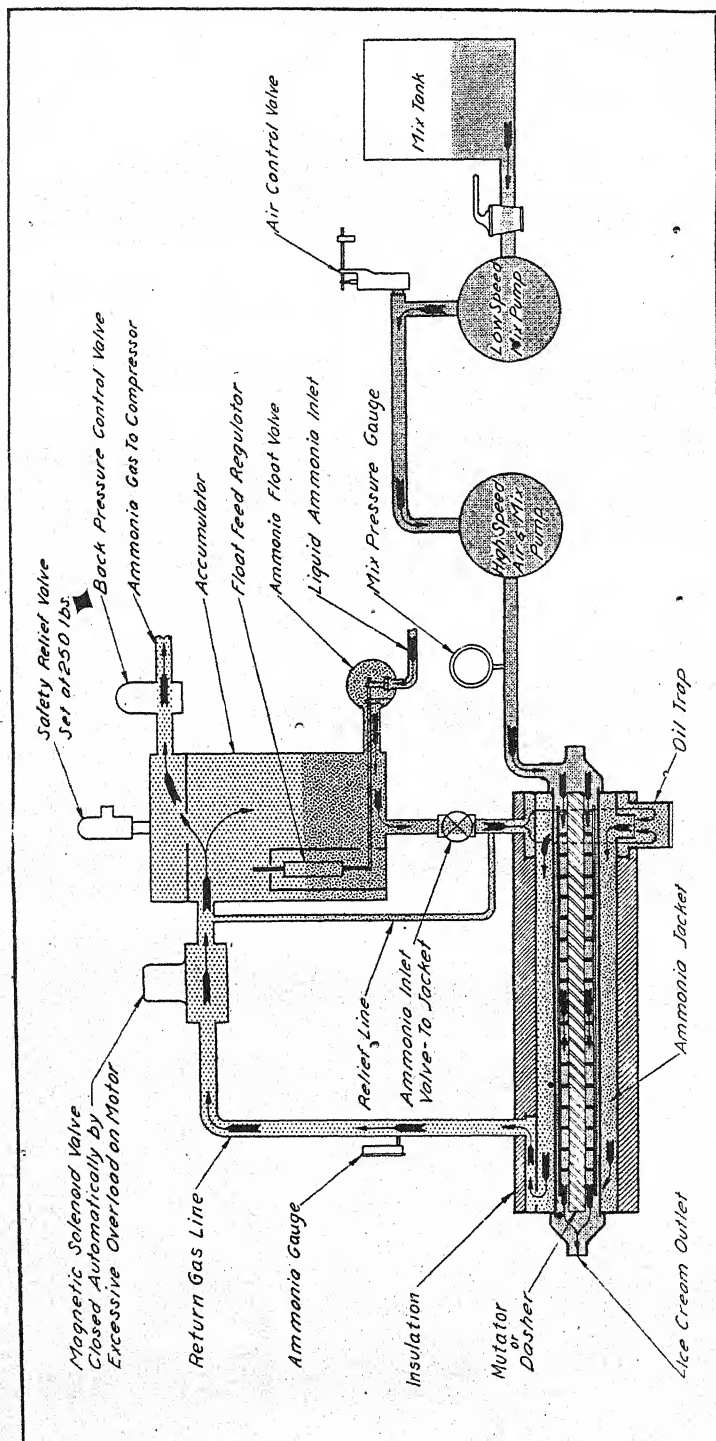
FIG. 14—The Cherry-Burrell Vogt Instant Freezer (Diagram of mix flow and ammonia control system)

By courtesy of Cherry-Burrell, Ltd.

Commercial freezers vary in capacity from 40 to 200 quarts. They are usually so arranged that the mix will flow by gravity from the ageing vats to the freezers, which may be either of the "batch" type or arranged for continuous operation.

The modern batch freezer consists of a refrigerator drum or cylinder which possesses a capacity of from 40 to 100 quarts. The machine is mounted on a base and is provided with direct motor drive which turns a dasher fitted with scrapers for removing the frozen cream from the refrigerated surface and a beater for whipping air into the mixture. It is also usually fitted with a mix tank and hopper for adding fruits and flavours.

When the "batch" system is in use, the mix is admitted from the hopper fitted above the barrel, fruit or fruit juices being added at this stage, if desired. A charge of mix usually half fills the apparatus, a 40-quart freezer being loaded with 20 quarts of mix. The mix is subjected to a beating action by dashers and scrapers, which revolve in opposite directions at 150 to 250 revolutions per minute. The blades of the dasher should always
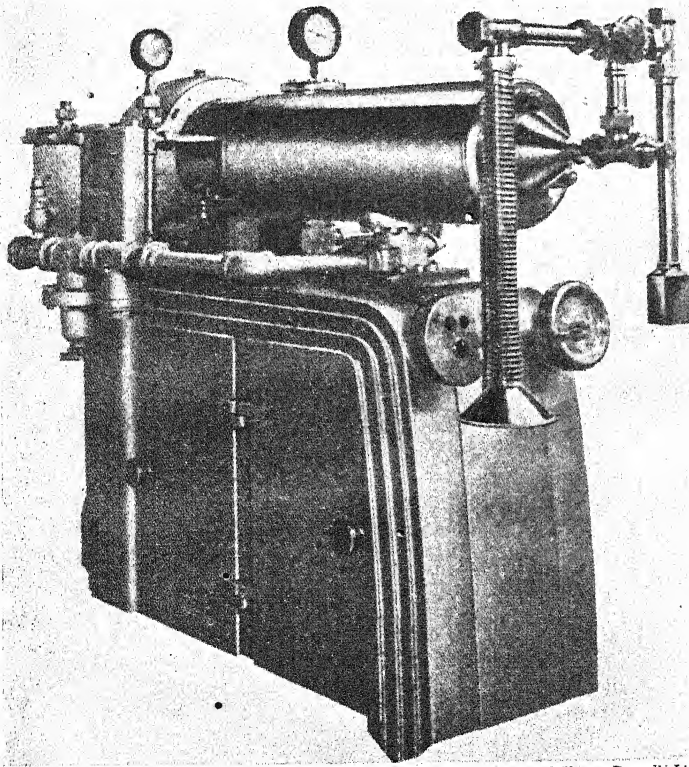
By courtesy of Cherry-Burrell, Ltd.

FIG. 15—Vogt Instant Freezer

be sharp and should scrape evenly upon the sides of the freezer. The mix should be beaten sufficiently to prevent the production of large crystals. The process occupies approximately twelve minutes, when the frozen cream is withdrawn at a temperature of 24° to 26° F. by means of the valve provided. It is then packed and conveyed to the hardening rooms. It is possible,

by means of an automatic device, to determine the correct factors of freezing and beating. The simplest device is a warning light operated thermally by the mix in the freezer. Many manufacturers withdraw the ice-cream before it is sufficiently frozen and in too soft a condition. When withdrawn from the freezer, it should be capable of flowing but should, in addition, be heavy and thick and form a dull, non-glossy mass without splashing. Premature withdrawal results in poor texture of the finished article due to the large crystals of ice which form during the hardening process.

Rapid freezing is essential if a smooth ice-cream is to be produced and for this reason brine temperatures should be in the neighbourhood of —5° to —10° F. There should be an ample flow of brine, the volume passing through the jacket should be approximately 50 gallons per minute for an 8-gallon freezer, while the mix should preferably be below 40° F. when it enters the apparatus.

During the last few years, a continuous-action type of freezer has been introduced and has resulted in a further advance in economy and quality. This method is not a profitable means of freezing unless large quantities are to be treated. The mix is frozen during its passage through the barrel, which passage occupies roughly one minute. A constant air pressure is maintained in the barrel by means of compressed air, while cork insulation is generally provided. The apparatus possesses a high-speed mutator or dasher (see Fig. 14) which agitates the mix, causing uniform contact with the walls of the freezing chamber and permitting quick heat transmission. The mutator rotates at a much faster rate than do the agitators or scrapers in other types of freezers, agitating the mix more uniformly and ensuring a surface which is free of insulation. It is possible to control the overrun exactly by regulating the speed of the pumps, an adjustment being provided for this purpose, while the mix is frozen at a temperature of 21° to 22° F. Ice-cream should not be run through this type of apparatus too rapidly, as if it is left in the freezer for a little longer period it will become dryer and a smoother texture will result.

The ice-cream is expelled from the freezing chamber through a tube directly into the container or final package. Ammonia is used as the refrigerant and this permits the employment of temperatures below 30° F. if required. The ice crystals present in the final product are both more numerous and much smaller when the mix is frozen in continuous freezers. This is important as there is a direct relationship between the ice-crystals and the cold effect upon the mouth and the distinctiveness of its flavour. A product containing large ice-crystals gives a cold feeling to the mouth with a consequent submergence of its flavour. In addition, large crystals give a poor texture. If ice-cream contains minute ice-crystals it gives a warm feeling in the mouth and this enhances its flavour, while the product possesses a smooth, even, close texture. Hardening requires less time, and packages may be filled direct from the freezer.

Overrun in ice-cream is extremely important, and care should be taken ﬓ ensure that too high an overrun is avoided or the ice-cream will melt in e mouth before there is time to taste it. Alternatively, if the overrun is tc. w a heavy, soggy product will result which is more distasteful to the majority of customers than is a highly aerated product. With the old type of freezer, the danger of too much or too little swell was easily avoided, but with modern, continuous freezers it is so easy to obtain a high overrun that many makers

are tempted to exceed a good business limit. It is usual to calculate the amount of overrun in proportion to the amount of solids in the mix. An ice-cream containing 35 per cent. total solids should possess an overrun of 8o to 85 per cent. and this would be a fair business proposition. A low overrun may be caused by prolonged whipping, as if this is carried to excess some of the air in the mix which has already been incorporated will be expelled. The amount of overrun may be ascertained by using an ordinary balance. A small container is filled, the top of the contents levelled off and
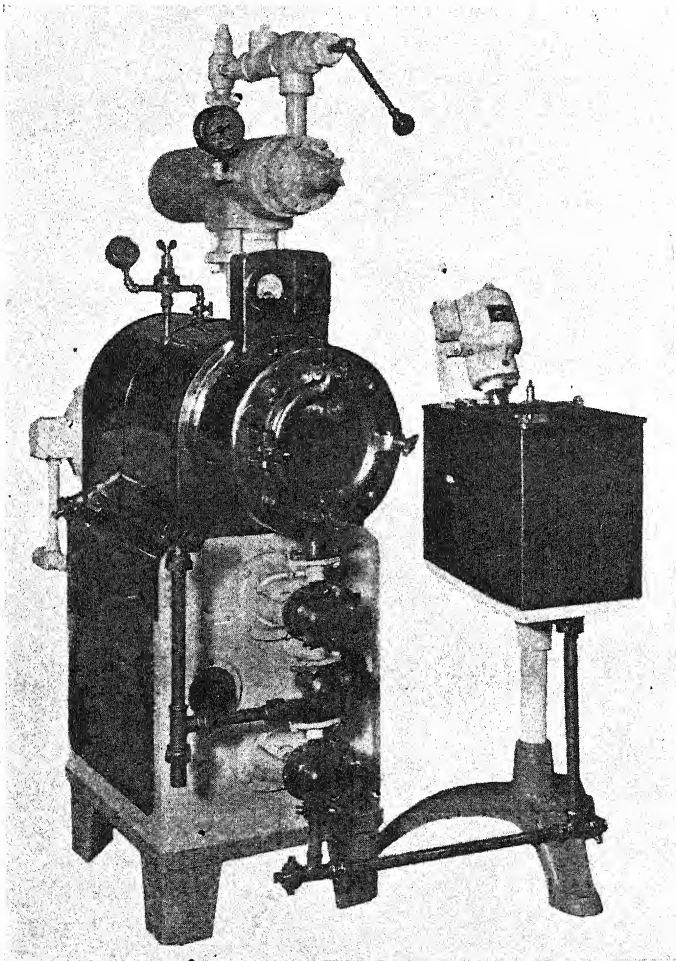
By courtesy of the Creamery Package Mfg.Co., Ltd.
FIG. 16—C.P. Continuous Ice-cream Freezer

the whole is weighed. When the ice-cream is ready to be tested, a sample from the mix is weighed in the same container. From the difference in the two weights, the overrun is simply calculated from the following formula:

$$\text{Overrun} = \frac{IC - M}{M} \times 100$$

where IC=Volume of ice-cream.
    M=Value of mix.

The following formula may also be used:—

$$\frac{\text{Weight of mix}}{\text{Weight of ice-cream}} \times 100 - \text{Weight of ice-cream} = \text{overrun}.$$

The weight of a gallon of mix is approximately $11\frac{1}{2}$ lb. The weight of a finished gallon of ice-cream having an overrun of 80 per cent. is approximately $7\frac{3}{4}$ lb. Whipping is influenced by the fact that milk does not freeze until the temperature reaches 27° F., while a too high sugar content will retard the freezing process.

It is important to note that ice-cream unsold at the end of the day should not be re-frozen. Not only will the bacterial content be increased, but an inferior product will result.

(*j*) *Hardening*.—This process may take place either before or after packing, and it is of considerable importance as the fine texture of ice-cream as it leaves the freezer may be destroyed by improper hardening. In the case of bricks or cartons, the product is hardened both before and after packing. The frozen cream is stored at a temperature of 0° to —30° F. for six to twenty-four hours. These low temperatures are necessary in order to ensure speedy hardening and to maintain the overrun. If the frozen cream is allowed to remain at the temperature at which it leaves the freezer for one or two hours, the air which it contains will gradually escape, the total bulk being thus diminished.

The frozen cream should be allowed to stand for at least twelve hours before being sold and, if pasteurised cream has been used in the mix, this period must be lengthened. If such is not done, an inferior article will be produced. Before the war, great strides had been made in continuous "tunnel" hardening at medium-low temperatures.

Hardening rooms should be heavily insulated with 6 to 9 inches of compressed cork in the form of slabs, these slabs being jointed with hot, odourless bitumen. Forced air circulation should be provided as this will sure rapid hardening, while the texture of the final product will be superior. Grids of piping carrying ammonia gas are also sometimes fitted. This piping may be arranged in three ways, according to conditions existing at the factory:

(i) The piping may be so fitted as to form shelves upon which trays of packages are stacked. Rapid hardening results owing to the articles being in close contact with the pipes.

(ii) Grids of piping may be fixed on the walls and suspended from the ceiling, thus allowing greater storage space.

(iii) Continuous hardening may be obtained by passing the packages on a conveyor belt through a tunnel, heavily insulated with cork slabs. A series of fans is used to drive the cold air on to the packages, the cold air returning round the sides of the tunnel to be recooled by the ammonia-filled piping placed around the fans. Very low temperatures, e.g. —30° to —40° F., are obtained by this method, small packages being hardened in approximately thirty minutes.

Fig. 17 illustrates a hardening room used for large-scale operations at a modern ice-cream factory. The floor of the hardening room should be constructed of granolithic cement, laid directly upon the insulation, while the internal finish to the cork must be sufficiently strong to remain free from cracking under the severe conditions to which it is subjected. The door is of vital importance, and particular care should be taken in its construction.

(*k*) *Packing*.—As already indicated, ice-cream may be packed either before or after hardening. A very high overrun is not desirable in packaged

ice-cream as none of the overrun is lost as is the case when it is served in portions. If the hardening process takes place after packing, the ice-cream is run from the freezer into moulds for hardening, prior to splitting and cutting into bricks. The product may also be run into 2- or 4-gallon cans, or into other containers, which are then capped, for bulk supply. When the ice-cream is filled into packages or cups immediately after freezing has been completed, the product should not be too hard. If such is the case, the filling of the containers will be difficult and the packages imperfectly loaded.

At the present moment, the greater proportion of the output of modern ice-cream factories is made up into bricks or cartons of varying sizes, and this method of packing is rapidly increasing in popularity. The cartons
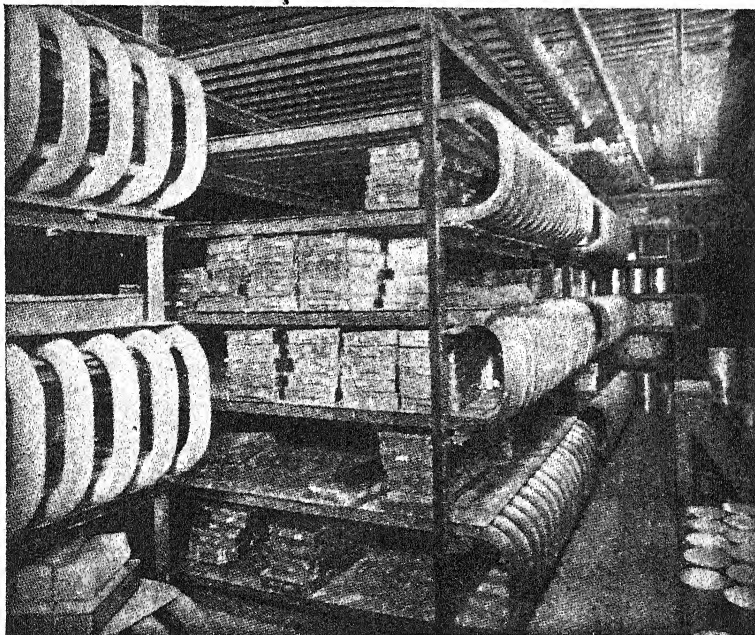
By courtesy of the Creamery Package Mfg. Co., Ltd
FIG. 17—Ice-cream Hardening Room

may be filled direct from the freezer on a rotary machine. The bricks are made from the moulds into which the hardened cream has been run after leaving the freezer. The solid block of cream is first cut, after which the separate portions are wrapped, packed, and rehardened before sale. Quick hardening is necessary to prevent the poor texture and the development of ice-cream crystals. There are now machines upon the market which will rapidly carry out these operations. They will perform the two-fold duty of cutting the ice-cream into bricks and wrapping them in printed parchment paper at the rate of over 70 per minute. Carton-making apparatus which will make and fill between 30 to 50 cartons per minute is also to be obtained. Figs. 18 to 21 illustrate various types of modern ice-cream packing machines.

In view of the large numbers of paper-wrapped ice-cream bricks now sold, the hygienic quality of the wrapping paper used assumes considerable importance. It is essential that only the highest quality paper should be utilised for this purpose.

Layer-brick ice-cream is the name given to the product when it comprises two or three coloured layers. The chilled mix from the freezer is run into a tray which is deep enough to hold three layers of the depth required. This tray is filled one-third full, its contents levelled and it is immediately returned to the hardening room. When the contents of the tray are sufficiently hard, another layer is added, the hardening process repeated and a third layer added later as desired. The slab is removed by dipping the tray in hot water to loosen its contents and it is then laid on a table and an air-blast applied to vent holes in the bottom which forces the ice-cream out of the container. It is then cut into bricks and wrapped. This type of ice-cream usually contains less overrun than the bulk variety, as no allowance for dipping pressure during serving needs to be made.

Storage and Distribution

Ice-cream, if improperly stored, tends to separate into its original constituents. The watery element which it contains freezes into sharp, icy particles, when the product will appear gritty to the palate. In order to conserve the product with a view to its profitable sale, it is therefore essential that it should be stored at a constant temperature. Well-made ice-cream will keep its colour and texture in good condition if held in the hardening
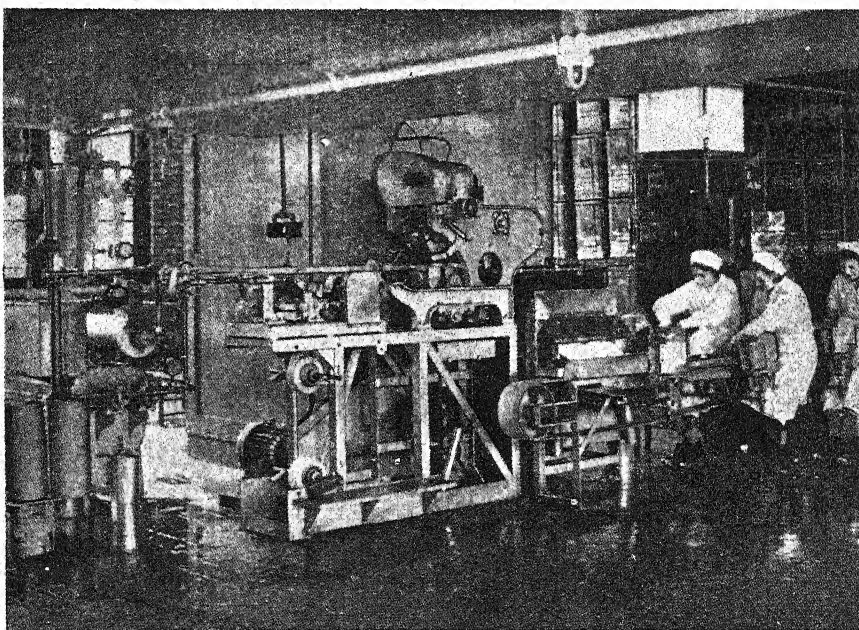
By courtesy of Cherry-Burrell. Ltd.

FIG. 18—Freezing, Hardening, and Cutting Apparatus

room at $-25°$ F., but if stored in a refrigerated shop cabinet it will exhibit changes in condition after a fortnight's storage. It is, however, subject to shrinkage as the result of excessive overrun, the incorporated air escaping during this period.

It is usual to provide insulated cans or boxes into which the 2- or 4-gallon packages of ice-cream or parcels, as the case may be, can be placed for storage. This insulation is now generally supplemented by the

use of solid carbon dioxide, although a few ice and salt outfits are still to be met with here and there. This type of freezing agent is generally used on the numerous delivery tricycles now seen upon the streets, while it is also employed for the speedy delivery of quantities of the product to shops, hotels, and restaurants. In appearance, solid carbon dioxide resembles hard, compressed snow, has a temperature of $-110°$ F. and it is sold under various proprietary names. There has been a rapid development in non-returnable cardboard packages which, when sealed, are strong and airtight. Their inside surfaces are finished in white wax and are perfectly hygienic. Little time is required for assembly and the cleansing of returned cans is unnecessary.

Solid carbon dioxide is also made use of in the refrigerated road vans or rail coaches. In such cases it is necessary to make use of some distributing device. This is arranged by fixing a coil of piping containing methyl chloride in such a way that it surrounds the solid carbon dioxide in an insulated receiver and is circulated through the evaporation coils which are fitted to the internal walls of the van or coach. When the temperature in the van falls to a predetermined level, a thermostatic device cuts out the circulation,
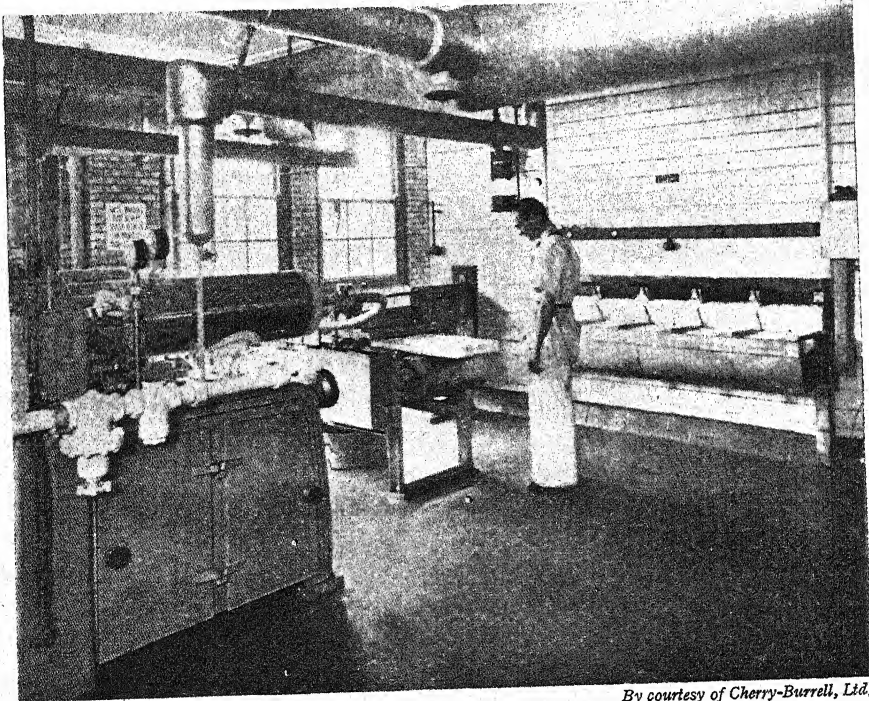
By courtesy of Cherry-Burrell, Ltd.

FIG. 19—Ice-cream Brick Extrusion

thus providing complete temperature control. Solid carbon dioxide posessess the following advantages:
(1) Light in weight.
(2) Produces no liquid on melting.
(3) Very easy to handle.
(4) It can be used for "take home" packaging with considerable success.
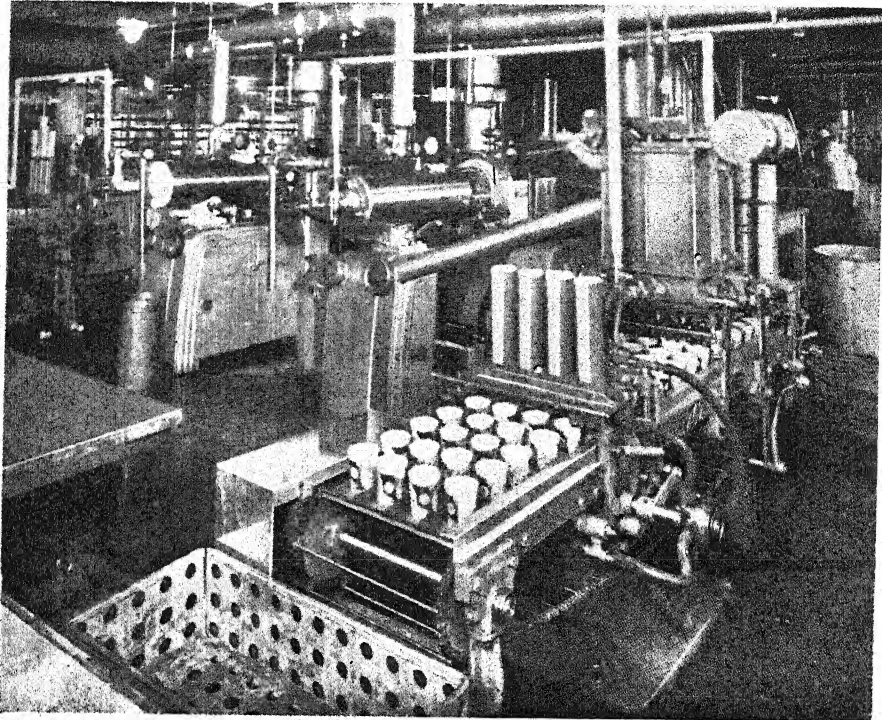
By courtesy of Cherry-Burrell, Ltd.

FIG. 20—Direct Cup Filling from Freezers

By courtesy of Cherry-Burrell, Ltd.

FIG. 21—Packaging for Shipment

The consumption of carbon dioxide per gallon of ice-cream varies according to the size of the conservator. One gallon of ice-cream can be maintained in good condition for twenty-four hours on 2 lb. of carbon dioxide while 4 gallons may be held for the same period with 4 lb. only.

Attempts have been made to produce eutectic "inserts" from ice and salt, but these are heavy, difficult to handle, and produce liquid on melting. Their use cannot, therefore, be recommended.

For the storage of cups and ice-bricks on retail premises, rectangular storage cabinets are used, as illustrated in Figs. 22 and 23. These cabinets are divided into two portions, a storage cavity and a refrigeration plant. The refrigeration apparatus is automatically controlled and operates with either methyl chloride, ethyl chloride, or Freon gas. Freon gas is being rapidly developed. It is non-poisonous, non-corrosive, and possesses no
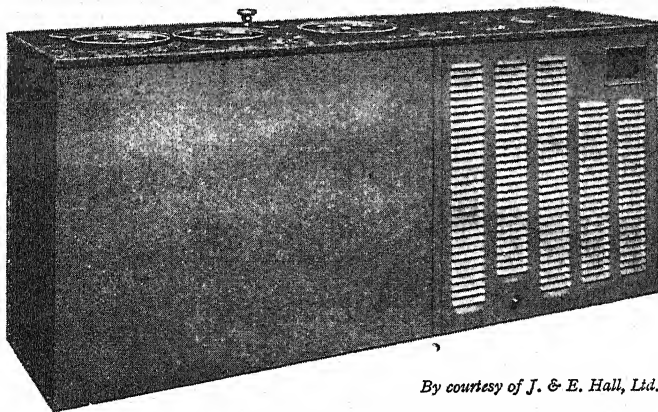
By courtesy of J. & E. Hall, Ltd.

Fig. 22—Self-contained Ice-cream Freezer-conservator (External)

odour. Such a refrigeration plant may be installed in road or rail vans and exhibits decided advantages over the method which makes use of solid carbon dioxide, being cheaper to operate, while possessing a continuous action as against the daily replenishment required with the latter substance. As this type of refrigeration plant operates by means of the direct expansion of gas, there is no likelihood of brine contamination, while the overrun imparted in the freezing process is retained. Thermostatic control is provided, and, owing to the high state of perfection achieved in manufacture, the apparatus will operate over a prolonged period with little or no attention beyond periodical servicing.

The motive power may be either gas or electricity. Although electrical operation may be satisfactory, many users have changed over to gas, which they consider more reliable. In the event of any failure in the supply of electricity, there is considerable likelihood that the contents of the cabinet will be damaged. The gas supply does not suffer from the same risk of failure.

Corkboard, granulated cork, bitumen, or crushed metal foil is generally used for insulation purposes and several layers are required to retain the necessary low temperatures. An expanded vulcanite insulation has been introduced, which, although more costly than the other materials mentioned, possesses decided advantages. It is rigid, light, and easy to handle, while, in addition, it also possesses excellent insulating properties.

Before the war, electrically-operated counter freezers combined with

storage cabinets made their appearance, and, as a result, the employment of a cold mix has become far too widespread. Refrigeration is obtained by electricity and is maintained with thermostatic control at the desired temperature. Allowance is made for the periodical rise and fall in temperature as the liquid brine is warmed up after each freezing operation and is then automatically lowered. For American-type ice-creams, a temperature of 0° F. or lower is maintained surrounding the freezer, with 10° F. in the cans from which the material is served. For Italian or cornflour ice-cream, a temperature of about 5° F. higher is considered more suitable. The average-sized apparatus holds about 8 gallons calcium chloride brine which requires to be "topped-up" as occasion demands. The mix is placed in the cans, frozen into ice-cream and then stored for sale in an adjoining can.

Ice-cream packed in cups and bricks of various sizes is rapidly replacing distribution in bulk and, from a hygienic point of view, this is a step in the
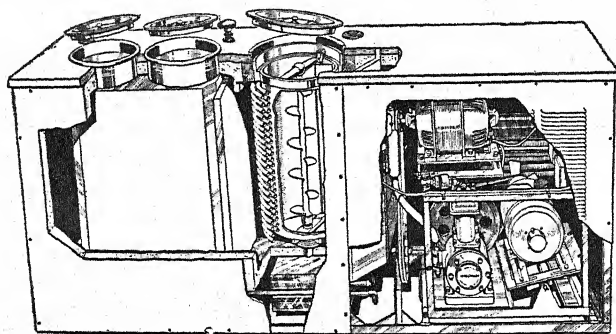
By courtesy of J. & E. Hall, Ltd.

FIG. 23—Self-contained Ice-cream Freezer-conservator (Section)

right direction. Factory-packed ice-cream can be produced under much more sanitary conditions than is the case with large numbers of retail shops. Direct distribution of the product by means of tricycles has largely influenced the development of the small package.

It is important to note that the Ice-Cream (Heat Treatment) Regulations, 1947, require that once frozen, no ice-cream shall be sold or offered for sale unless it has been stored at a temperature not exceeding 28° F. since manufacture. Should the temperature rise above this level, the product must be re-processed, cooled, and stored at temperatures set out by the Regulations.

Sterilisation of Plant

Any plant which is responsible for the manufacture of foodstuffs must of necessity be efficiently cleansed and sterilised. Ice-cream manufacturing plant is no exception to this rule, and emphasis must again be placed on the word *"efficient."* It should be remembered that the objects of cleanliness and efficiency in production are two in number:

(1) To ensure a *high-quality* product; and
(2) To ensure a *safe* product.

However much the *quality* of the finished article is to be desired, the *safety* of the article remains the paramount desideratum from a public-health viewpoint.

The cleansing methods practised by the average "back-yard" producer of ice-cream cannot be termed satisfactory in any sense of the word. It is

difficult to sterilise satisfactorily without steam, and it should be remembered that these vendors possess no facilities for the generation of steam for this purpose. Really hot water is suitable for the purpose, but again the small vendor does not possess the means of retaining such water in a sufficiently hot condition. Further, it would appear an unwise proceeding to suggest the use of chlorine solutions by the small vendor. Their normal method of sterilisation is to rinse out receptacles with cold water, this operation being followed by a wash in hot or lukewarm water. The utensils are then wiped out with a rag, which is often itself in a soiled condition.

An article may be said to be sterile when it harbours no living bacteria or spores. After a preliminary washing first in cold and then in hot water, the utensils must be rendered free from living organisms by sterilisation, and, as already stressed, this is only possible by the use of steam, really hot water, or chlorine solutions for the final treatment. It should be emphatically stated that there is *no substitute for these three methods in the sterilisation of utensils*, although it is also necessary to point out that such sterilisation should only follow a thorough cleansing of the articles concerned.

Many ice-cream producers state that they sterilise their utensils by means of boiling water. The value of this statement becomes apparent when it is remembered that the term "scalding" includes anything from washing out with lukewarm water to the use of really boiling liquid. In all such cases, the temperature of the water used varies according to the distance which it has to be carried, while there is a further drop in temperature when the water comes into contact with the article to be treated. It is this temperature drop which is the cause of inefficiency, since it cannot be overcome by any means available to the small producer. This method still has its advocates, as it is simple and involves no capital outlay, but it cannot be too strongly emphasised that there is no comparison between scalding and efficient sterilisation.

It has already been stated that sterilisation, which is entirely a matter of temperature, must be efficient, and, to procure such efficiency, certain conditions must in turn be observed. When steam is employed, these conditions are:

(1) The steam should be quickly available and should issue from the outlet pipe within a limited time.

(2) The steam pressure must be retained throughout the steaming.

(3) It is impossible to sterilise efficiently unless the utensils are effectively covered.

(4) The sterilisation should be carried out in a situation free from air currents.

(5) Some adequate means of checking the temperature is essential.

The length of time during which the steaming process should be maintained depends upon the apparatus to be treated, but in all cases the temperature must be maintained at 210° F. Following efficient sterilisation, there should be no condensed water upon any of the surfaces treated, as the heat of these surfaces should be sufficient to dry off any reasonable quantity of condensed moisture. Should any moisture be present, no attempt should be made to remove this, as such efforts will undo the work already undertaken. It should always be remembered that sterilisation is like a chain, no stronger than its weakest link, and all surfaces should be sterilised.

Generally speaking, steam is only practicable when all surfaces can be brought up to sterilising temperature. Hot water is useful but care must be taken to ensure that it comes into contact with all surfaces for a sufficient

length of time and its temperature on discharge should never be lower than 180° F. Chlorine solutions to which sodium metasilicate has been added to reduce the corrosive effect can be successfully employed. Rinse solutions should have a strength of 100 parts per million, while tanks should be sprayed with a solution of 300 p.p.m. It is important to ensure that all surfaces are covered, while all pipe fittings, valves, etc., should be left loose so that chlorine will not form pockets in the equipment. Chlorine strengths should be checked daily.

The process of cleansing and sterilising should always be methodical. Immediately after processing has been completed, the equipment should be rinsed out with cold water, the usual custom being to pump cold water through the plant for a period before dismantling is begun. The pasteurisers should be filled with hot water at 120° F., together with detergent, and the sides brushed with a stiff brush. The solution in the pasteuriser should then be pumped through the homogeniser and cooler into the ageing vat, each piece of apparatus being scrubbed in turn. Clean hot water at 180° F. should then be drawn through the plant to wash off the detergent. The homogeniser, pipe-lines, valves and other removable parts which come into contact with the mix should next be dismantled, thoroughly brushed and rinsed with hot water at 180° F., and the parts, with the exception of the dismantled pipe-lines, placed in a sterilising chest and steamed for fifteen minutes.

The pipe-lines should then be reassembled and flushed with hot water at 180° F. for fifteen minutes, care being taken to ensure that this comes into contact with the whole of the inner surface of the pipes. Steam may then, if desired, be blown through the assembled pipe-lines for fifteen minutes.

When the period of steaming has been completed, the smaller articles should be dried off by opening the door of the sterilising chest, thus allowing the steam to escape, after which the door should be closed for a few minutes.

Steam should be blown into the pasteurisers and ageing vats for fifteen minutes, while the surface of the cooler, if of the open type, may be sprayed with steam. If the cooler is of the plate heat-exchanger type, the apparatus should be opened and the plates scrubbed with clean hot water on either side, after the final washing with hot water at 180° F. for fifteen minutes. The apparatus should finally be reassembled, and steam may be blown through for fifteen minutes, if available. Sterilisation is best carried out as shortly as is practical before the apparatus is again used.

The cleansing and sterilisation of the freezers must not be overlooked. When freezing operations have been completed, any ice-cream remaining in the apparatus should be drained off and the strainer, hopper, and exterior of the apparatus rinsed with cold water. The freezer should be half-filled with cold water and operated for at least one minute, after which the water should be drained off. The entire apparatus should then be washed with *hot* water at 180° F. and detergent, all parts being thoroughly scrubbed with a stiff bristle brush. The dashers or beaters should be removed for a separate cleansing, after which they may be replaced. Steam or hot water at a temperature of 180° F. should next be admitted into the freezer from a special removable pipe for ten minutes, following which the apparatus should stand until required for use.

When the plant has been cleansed and sterilised, the floors should be scrubbed with a stiff bristle brush and hot water applied. Tri-sodium

phosphate or sodium metasilicate will be found to be suitable cleaning agents for floors, while soap solutions are suitable for walls. Tables and shelves should be washed and scrubbed daily.

In short, *absolute and unvarying cleanliness is essential.*

Manufacturing Problems

The manufacturer of ice-cream has many difficult problems to face, particularly during winter. A reduced winter demand implies fewer mixes, fewer freezings, and longer storage periods, not only for the ingredients but also for the finished product. Prolonged storage favours the development of flavour defects which are the result of certain physical or chemical changes either in the mix or in the manufactured article.

Several investigators have studied the effect of certain metals in relation to milk and have proved that iron, copper, and certain nickel alloys may be the cause of tallowy or metallic flavours. These flavours may obtain entrance to the milk as a result of the use of improperly tinned farm or plant equipment. Milk contaminated in this manner will affect the flavour of the ice-cream, if used in the mix. If the mix is concentrated in a copper vacuum pan, the flavour of the product will be affected. If copper surfaces are maintained in a bright condition, free from metallic oxides, such surfaces will not be a serious source of off-flavours, but it should be remembered that copper corrodes rapidly when not in frequent use.

During the winter months, ice-cream is stored for longer periods in the hardening room or in the dealer's cabinet. If a tallowy flavour is at all present in the ice-cream, prolonged storage at low temperatures will emphasise this defect. Laboratory experiments have shown that tallowiness is more likely to occur in milk which possesses a low bacterial content, and this may provide an explanation of the increased difficulty experienced in this direction during the winter period.

Cream and unsalted butter are kept in cold storage for varying periods during the winter months. During such times, the fats contained in these products may undergo certain chemical changes. This is particularly the case if metals are present, if the storage temperature is not sufficiently low, or if the articles are exposed to the air. This results in the fat, which may have been of good flavour when introduced into the mix, becoming tallowy shortly after it has been frozen into ice-cream (owing to the progression of the induction period during storage and by the subsequent processing being carried out in contact with metal surfaces).

Ice-cream manufactured from poor-quality butter-fat generally acquires a stale, tallowy flavour much more quickly than does a product in which fat of high quality has been used. Copper salts are usually responsible for the rapid development of this defect.

When ice-cream is consumed, it occasionally produces a rough, powdery sensation upon the tongue, and is then said to be "sandy." This defect is the result of the presence of lactose or milk-sugar crystals. At hardening-room temperatures, the solubility of milk sugar in water is rather low. Therefore, when a certain concentration of milk sugar in the mix is exceeded because of a high serum solids or a high total solids content, the lactose may crystallise, thus producing the "sandy" condition. Fluctuating temperatures in the hardening room or in the dealer's cabinet will hasten the formation of lactose crystals. In order to avoid this defect, the milk-sugar

content of the mix should not exceed 8·5 per cent. of the water content.

A lack of salt balance in the milk from which the mix is made may result in slow whipping in the freezer. Winter mixes whip more slowly than do summer mixes of identical composition. Calcium citrate or phosphate salts should be used to balance the salt shortage, the substance used depending upon which particular salt is lacking. A second reason for slow whipping in winter is the use of butter or frozen cream as a source of fat. If frozen cream is used, the addition of sugar before freezing will accelerate the whipping process. This tends to prevent the churning of the butter-fat in the freezer, while the thawing of the cream enables the fat to remain as a normal emulsion.

It is important that the scraper blades of the freezer should be properly maintained. If these are allowed to become dull the efficiency of the apparatus is decreased, while the body and the texture of the ice-cream will be impaired. The quick transference of heat, which is so essential, will be considerably decreased due to insulation through ice forming on the internal surfaces of the freezer. The time required for freezing depends upon the degree of dullness of the blades, up to 75 per cent. increase in time required for freezing being necessary according to their condition.

Bacteriological Control

The bacteriological control of ice-cream supplies is as important as that of milk, particularly in view of the increasing quantity annually produced and consumed, together with the ease with which the product may be contaminated or recontaminated. The following information may be obtained as the result of bacteriological examination:

(a) A measure of the general bacterial and *Bacillus coli* content.
(b) An estimation of the presence or absence of definite pathogenic organisms.

The routine of determining the non-pathogenic and pathogenic bacterial content of ice-cream may be divided into the following stages:

(1) Collection of samples.
(2) Estimation of total bacterial content.
(3) Estimation of *Bacillus coli* content.
(4) Examination for pathogenic bacteria.

(1) **Collection of Samples.**—Wide-mouthed, glass-stoppered bottles or jars of 125 mls. capacity are required for this purpose, together with spoons which are necessary in certain cases for filling the bottles with the frozen product. Bottles, containers, and spoons should be efficiently sterilised in a hot-air oven for one and a half hours, at 180° C., in order to ensure complete destruction of all bacteria and spores. The spoons should be inserted in copper cases before sterilisation, and the case and spoon should be sterilised together. The spoon should not be removed from the case until required for use.

Samples may be taken at various points during production and distribution, as follows:

(a) *Direct from the pasteuriser* to test the efficiency of the treatment and for examination by the phosphatase test. Samples obtained at this point should be collected by means of a sterilised dipper.

(b) *Before Freezing but following Homogenisation.*—Samples obtained at this point should be collected directly into the bottle by passing same under the opening of the apparatus at periodic intervals, in order to ensure that a representative sample of the mix is obtained.

(c) *From the Ageing Vats.*—Samples obtained at this point should be collected from the vat by means of a sterile spoon, and placed in the jar or bottle. The contents of the vat should be agitated by the mechanical means provided, before the sample is taken.

(d) *On leaving the Freezer.*—Such samples should be collected at intervals directly into the bottle or jar immediately the product leaves the apparatus, in order to ensure a representative sample.

(e) *From Cans after Hardening.*—In such cases the upper layer of ice-cream to a depth of 1 inch should be removed by means of a sterile spoon, following which the sample proper should be obtained by a second sterile spoon and placed in a sterile jar.

(f) *Samples taken at Retail Premises or during Distribution, when packed in Bricks or Cartons.*—In such cases, the cartons or bricks should be forwarded to the laboratory unopened.

(g) *From Cans at Retail Premises or during Distribution.*—Such samples should be taken in a similar manner to those mentioned under (e).

In every case, the quantity of ice-cream obtained should be at least 50 mls., while the samples, after collection, should at once be forwarded to the laboratory where they are to be examined. Unless samples are properly cared for after collection, the information obtained from bacteriological examination will not be representative of the material, and is likely to be useless.

Samples should be packed in insulated boxes, the sample jars being placed in metal, water-tight containers which should in turn be surrounded with ice and salt, or preferably solid carbon dioxide.

(2) Estimation of Total Bacterial Content.

—The examination of a sample of ice-cream for total bacterial content follows closely upon the lines of the plate count examination of a sample of milk. The media used is prepared from peptone, yeastrel, agar, fresh whole milk, and water distilled in glass.

The frozen ice-cream should be melted in a container placed in a water bath at 45° C. for a period not exceeding fifteen minutes. A higher temperature is undesirable, as a proportion of the bacteria may then be injured, while, at lower temperatures, organismal growth may take place. During the heating process, the sample should be stirred with a sterile glass rod in order that the air contained in the product may be expelled.

In making the original dilution, error can be reduced by using a reasonably large amount of the cream. For this reason, the primary dilution should be made with 90 mls. of sterile water plus 10 mls. of the product. Thereafter, dilutions of 1 in 100, 1 in 1,000, and 1 in 10,000 may be made from the primary dilution.

Not more than fifteen minutes should elapse between making the dilutions and plating the samples. Three or more Petri dishes are required, one for each dilution. One millilitre of the 1 in 10 dilution is transferred to the Petri dish, the cover replaced, and the same procedure carried out with each of the remaining dilutions. During the process, the tubes containing the media should be heated in a water bath and the melted agar poured over the dilution in each dish at a temperature of 45° C. The contents of the dish should be thoroughly mixed while the media is still liquid. The dishes should stand in a perfectly horizontal position to ensure a uniform depth of the media and should be allowed to remain in this position until solidification has taken place. The plates should then be incubated for forty-eight hours at 37° C.

The numbers of colonies on the plates should be counted as soon as practicable after removal from the incubator. Counting operations should always be carried out by inverting the dish over a counting desk illuminated from below. The colonies on each plate should be marked off with either a pen or a special pencil, and the total number multiplied by the dilution. The total number of colonies on all the plates should then be added together and divided by the number of plates counted. This gives the total number of bacteria in one millilitre of the product examined.

The interpretation of the results is important. High bacterial counts are primarily due to four main factors:

(a) Poor-quality raw materials.
(b) Improper processing, i.e. inefficient pasteurisation or ageing over too long a period or at too high a temperature.
(c) Unsatisfactory cleansing and sterilisation of equipment.
(d) Carelessness of employees.

It will be readily understood that an excessive number of bacteria discovered in a sample of ice-cream does not necessarily imply an unsatisfactory product as regards constituent components. Rather is it an indication of an article produced in an unsatisfactory manner. It should also be remembered that it is not possible by means of a plate count to differentiate between pathogenic and non-pathogenic bacteria. On the other hand, high plate counts are an indication that the treatment of the ice-cream is not as it should be, and it is, therefore, essential that the cause of any high counts should be immediately traced and removed.

It is advisable to make a direct microscopic count in conjunction with the plate count, in order to check the results obtained from agar plates. This test is carried out by spreading 0·01 ml. of the melted ice-cream over an area of 1 sq. cm. on a sterile glass slide. The material is fixed and the fat removed, the slide being then treated with Newman's stain and examined microscopically.

(3) **Estimation of Bacillus Coli Content.**—The dilutions used in the plate count are also employed in the estimation of the *Bacillus coli* content. Five double tubes, each containing 10 mls. of MacConkey broth, are required, four of these tubes being inoculated as follows:

Tube 1.—1 ml. of the melted ice-cream.
Tube 2.—1 ml. of the 1 in 10 dilution.
Tube 3.—1 ml. of the 1 in 100 dilution.
Tube 4.—1 ml. of the 1 in 1,000 dilution.

One tube is left uninoculated as a control tube, but is incubated with the others at a temperature of 37° C. for forty-eight hours, the tubes being examined for the presence of acid and gas at the end of that period. If coliform organisms are present, the media will become acid, while gas will be present in the inverted fermentation tube.

The presence of coliform organisms may also be detected by inoculating each of three tubes containing MacConkey broth with 0·1 ml. of ice-cream and these are incubated for forty-eight hours at 37° C. The remainder of the sample is incubated at 20° C. until the following morning when 0·1 ml. is inoculated into MacConkey broth. All tubes which show acid and gas are sub-cultured to fresh tubes of the same medium and incubated at 44° C. to determine whether or not the organisms are of the faecal type.

Coliform bacilli should not be found in ice-cream if the mix has been

efficiently pasteurised, although they are not readily killed by such a process owing to the added sugar which the mix contains. For this reason, as previously indicated, the mix is usually pasteurised at a higher temperature than that at which milk is treated.

It should again be stated that the presence of coliform organisms in a sample of ice-cream does not necessarily mean that such organisms are dangerous to man. In the absence of more definite proof, however, their presence should invariably be taken as an indication of some inherent fault in the product and not lightly dismissed as a matter of slight importance. This is particularly necessary in view of the potential fæcal origin of this group of organisms. The test for coliform organisms also provides an extremely good check on plant sanitation.

(4) **Examination for Pathogenic Organisms.**—The usual examinations required to detect the presence of pathogenic organisms in ice-cream depends upon the cases of infection which may arise following the consumption of the product. Examinations are usually made for the presence of the following organisms:

(*a*) Hæmolytic streptococci.
(*b*) Typhoid and paratyphoid bacilli.
(*c*) Dysentery bacilli.
(*d*) Organisms causing food poisoning.

(*a*) *Hæmolytic Streptococci.*—A platinum loopful of the centrifugalised deposit obtained from 100 mls. of melted ice-cream is smeared upon a glass slide, fixed by heat, and stained by Gram's method. If streptococci are found, a further loopful of the deposit should be smeared on the surface of a Petri dish containing blood agar media, and incubated for forty-eight hours at 37° C. Colonies of hæmolytic streptococci which appear should be further examined for complete identification.

(*b*) *Typhoid and Paratyphoid Bacilli.*—To isolate these organisms, a loopful of the sediment obtained after centrifugalisation is plated out upon the surface of MacConkey's bile-salt neutral-red agar. If the organisms are present, colonies will appear following incubation at 37° C. for approximately eighteen to twenty-four hours. These colonies show as paler units than the more usual pink colonies of bacillus coli, and such colonies should be picked off and sub-cultured. The pure cultures isolated are then subjected to fermentation tests. Table 2 illustrates the method by which typhoid and paratyphoid bacilli and other intestinal organisms may be distinguished.

TABLE 2

	Lactose	Glucose	Mannite
B. coli group	Acid and gas	Acid and gas	Acid and gas
B. typhosus and B. dysenteriæ Flexner Y	No change	Acid only	Acid only
B. paratyphosus A and B .			
B. enteritidis Gaertner . .	No change	Acid and gas	Acid and gas
B. aertrycke . . .			
B. dysenteriæ Shiga . . .	No change	Acid only	No change

(*c*) *Dysentery Bacilli.*—In certain cases it may be necessary to examine ice-cream samples for the presence of these organisms. It is not intended in a volume of this description to describe the process in detail, it being sufficient to state that the organisms are first isolated and then distinguished by means of fermentation tests (see Table 2).

(d) *Organisms of Food Poisoning.*—It is occasionally necessary to determine the presence or absence of the causative organisms of food poisoning in ice-cream. It again appears sufficient to state that these organisms are isolated and then distinguished from other intestinal organisms by means of the fermentation tests set out in Table 2. The food-poisoning organisms more commonly found in ice-cream are the *Bacillus enteritidis* of Gaertner and *Bacillus aertrycke.*

Chemical Examination

The chemical examination of ice-cream is usually carried out with a view to ascertaining the percentage of butter-fat, total solids, and nitrogen present, together with the presence of colouring matter and gelatine.

Before any such examination can be carried out, careful preparation of the sample, which should be representative of the bulk of the product, is necessary. It is usual to allow the material to soften at room temperature, since, if artificial heat is applied for this purpose, the melted butter-fat tends to separate out and rise to the surface. When liquid, the sample should be well mixed by pouring from one receptacle to another. This is especially important in the case of unhomogenised or "soured" mixes.

(1) Examination for Butter-fat.—The percentage of butter-fat in ice-cream may be obtained in two ways:

(a) Gerber method.
(b) Roese-Gottlieb method.

No officially approved method exists in this country for the examination of ice-cream, although the Roese-Gottlieb test mentioned below has been recommended by the Society of Public Analysts and is officially approved in the United States of America.

(a) *Gerber Method.*—It should be pointed out that experiments have shown that no one method of volumetric examination is suitable for use with all types of flavours of ice-cream. With the Gerber method, 10 mls. of sulphuric acid (s.g. 1·815) are first measured into a standard milk butyrometer. By means of a wash bottle, distilled water is carefully added until the acid is covered to a depth of 6 mm. Five grams of melted ice-cream are weighed out into a suitable weighing funnel and are washed into the butyrometer with warm distilled water. One millilitre of amyl alcohol is then added and the butyrometer is filled to the shoulder with water. The butyrometer is then stoppered and well shaken until no solid particles can be seen, after which it is centrifuged for five minutes. The tube is then tempered in a water bath at 68° C., after which the reading is taken. This figure multiplied by the factor 2·218 gives the fat percentage.

(b) *Roese-Gottlieb Method.*—This is the only gravimetric method of fat estimation which is capable of yielding accurate results with effectively homogenised ice-cream mix. This method was first introduced by Roese in 1888 for the examination of milk, was modified by Gottlieb in 1892 and first applied to ice-cream in 1913 by Leach, while between 1917 and 1921 Majonnier patented certain modifications and designed and marketed the well-known Majonnier tester. Four grams of the sample are placed in a small, dry beaker, and to this are added 3 mls. of water, the whole being mixed with a glass rod. This mixture is then transferred to a Gottlieb extraction apparatus, 3 mls. of water being used to wash out the remaining mixture in

the beaker. Two millilitres of concentrated ammonia are added, mixed thoroughly, and the whole heated in a water bath at 60° C. Ten millilitres of 95 per cent. alcohol are next added, and the solution thoroughly mixed. After mixing, 25 mls. of ether are added, the mixture is shaken vigorously for thirty seconds, a further 25 mls. of petroleum ether are added, and the whole mixture is again shaken for thirty seconds. The mixture is allowed to stand for twenty minutes or until such time as the top layer is clear. As much as possible of the ether fat solution is siphoned off into a flask through a filter and washed through with a further 5 mls. of solvent. The liquid remaining in the tube is extracted with 15 mls. each of ether and petroleum ether, shaken vigorously for thirty seconds after each addition, and allowed to settle. A third application is supplied to ensure complete removal of the fat. The combined extracts are then evaporated slowly in a water bath and the residue dried off to constant weight. The fat is removed by means of petroleum spirit and the residue dried to constant weight. The fat percentage is then calculated by difference. This method is more accurate than the Gerber test, and is generally used in the laboratory examination of ice-cream.

(2) Total Solids Content.—No officially approved method for the examination of total solids content of ice-cream yet exists in this country. One gram of the sample is placed in a dish, the weight of which is already known, and the whole is re-weighed. One to 1·5 mls. of distilled water are added to dilute the sample in order that it may spread evenly over the base of the dish. The dish containing the sample is then placed in a water bath and the contents evaporated to dryness. When the dish with its contents is dry, it is removed to a steam oven where it is given a further drying for a period of one hour. The contents are cooled and weighed, then heated and re-weighed until the last two weights are constant. The percentage of total solids can thereafter be calculated.

(3) Nitrogen Content.—To ascertain the nitrogen content of ice-cream, Kjeldahl's method is used. Four to 5 grams of the product are placed in a glass digestion flask, and to this are added 10 grams of powdered
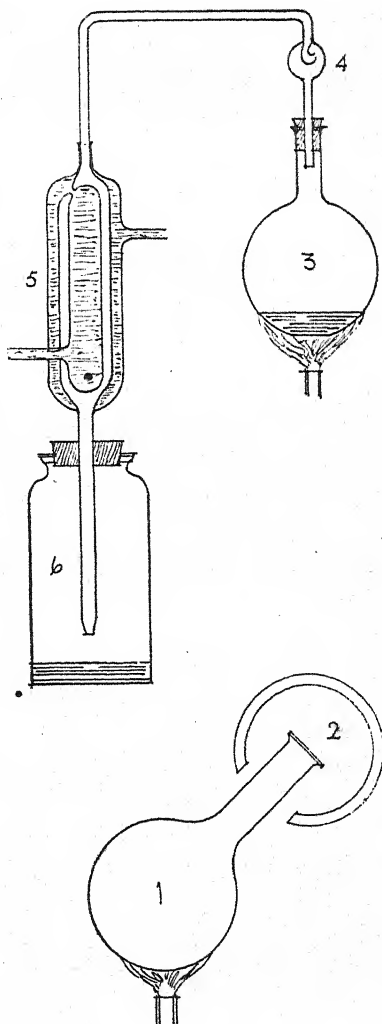
FIG. 24—KJELDAHL'S APPARATUS

1. Glass Flask   4. Water Trap
2. Draught Pipe   5. Condenser
3. Copper Vessel   6. Receiver

potassium sulphate, 25 mls. of concentrated sulphuric acid, and one small crystal of copper sulphate. The flask is heated until the contents are thoroughly carbonised, after which it is strongly heated until a clear green liquid is obtained. During the process the organic matter is thoroughly broken up, the nitrogen being converted into ammonia, which is the clear solution remaining in the flask. This is washed out of the glass flask into a copper vessel with distilled water. Sufficient caustic-soda solution should be added to render the mixture strongly alkaline, and the condenser tube fitted with a water trap. A condenser is also fitted to the copper vessel.

The receiver contains 10 mls. of normal sulphuric acid slightly tinted with methyl orange as an indicator. This is placed below the condenser, heat being applied to the liquid in the copper vessel. The solution, on boiling, frees the ammonia, when the gas passes to the condenser with the steam and falls into the sulphuric acid. The distillation process is carried on until the ammonia has completely passed over. The receiver is removed and the liquid which it contains titrated with normal caustic-soda solution until the red colour of methyl orange changes to yellow. The amount of caustic soda used is noted. The formula for finding the percentage of nitrogen is:

$$\text{Percentage of Nitrogen} = \frac{0 - B \times \cdot 014 \times 100}{A}$$

where A = Weight of ice-cream in grams ; and

B = Amount of normal caustic soda required to neutralise the acid in the receiver.

(4) Presence of Colouring Matter.—Low-grade ice-creams often contain colouring matter, principally *annatto*. The test for the presence of annatto is carried out in the following manner. One hundred and fifty to 200 grams of melted ice-cream are curdled by adding an equal volume of water, together with 10 to 20 grams of acetic acid. The mixture is heated to a temperature of 70° to 80° C., stirring being continued during the entire period. It is then allowed to cool. The whole is strained to separate the curd from the whey. The curd is next pressed free from liquid, transferred to a small flask, macerated, and allowed to stand overnight in 50 mls. of ether. The flask should be tightly corked and shaken at intervals. The ether extract is decanted into an evaporating dish, the ether evaporated, and the residue made up with sodium hydroxide. This mixture is poured over a small, moist filter. If annatto is present, the filter will absorb the colouring matter and, when washed with a stream of water, present a straw coloration. The filter paper should be dried and a drop of stannous chloride solution added, when a pink coloration confirms the presence of annatto.

(5) Presence of Gelatine.—Gelatine is a constituent of many ice-cream mixes, and it may be necessary to prove its presence in a sample of the product. Ten ml. of acid prepared by dissolving mercury in twice its weight of nitric acid, the whole being diluted to 25 times its volume with water, are added to 10 mls. of melted ice-cream. The mixture is well shaken, 20 mls. of water added and the mixture again shaken, the whole being allowed to stand for five minutes, after which it is filtered. A portion of the filtrate is placed in a test-tube and to this is added an equal volume

of saturated aqueous picric-acid solution. A yellow precipitate indicates a considerable quantity of gelatine, smaller quantities producing cloudiness only. If no gelatine is present, the filtrate will remain clear.

(6) Resazurin Test.—The employment of this dye enables the operator to classify the incoming milk within a short period of time after its arrival at the plant, and it should be employed to all milk prior to its manufacture into ice-cream. The technique of the test consists of adding 0·1 ml. of a 0·05 per cent. solution of resazurin to 10 mls. of milk. The mixture is incubated at 37° C. in a water-bath protected from light, and after one hour has elapsed, comparison is made with a standard colour-glass disc. The colour changes from blue through pink to white according to the bacterial quality of the milk.

(7) Methylene-Blue Reductase Test.—This test is now recommended as suitable for ascertaining the bacterial cleanliness of ice-cream. Two millilitres of ice-cream are added to 1 ml. of methylene-blue solution and 7 mls. of sterile, $\frac{1}{4}$-strength Ringer solution. The tubes are incubated in a water-bath for 17 hours at 20° C. after which they are transferred to another bath at 37° C., being then observed at half-hourly intervals. The time taken for decolorisation is recorded and the samples graded as follows :

Grade 1.   Decolorised in $4\frac{1}{2}$ hours or more.
Grade 2.   Decolorised in $2\frac{1}{2}$–4 hours.
Grade 3.   Decolorised in $\frac{1}{2}$–2 hours.
Grade 4.   Decolorised in less than $\frac{1}{2}$ hour.

If the sample is decolorised on removal from the 20° C. bath, the time is recorded as o hours. The following control tubes are required :

1. Tube with 2 mls. ice-cream mixed with 8 mls. $\frac{1}{4}$-strength Ringer solution incubated as mentioned above.
2. Tube containing 5 mls. ice-cream which has been heated for 15 minutes in boiling water, cooled and used in the test proper.

(8) Phosphatase Test.—A properly pasteurised mix should show no phosphatase activity. In carrying out the test, 0.5 ml. of mix is added to a test-tube containing 10 mls. of buffer-substrate solution. To this are added three drops of chloroform, the tube is sealed and incubated for twenty-four hours at 37° C. The tube and its contents are cooled at the expiration of this period and 4·5 mls. of Folin's reagent added, allowed to stand three minutes and then filtered to the 10 mls. mark in a fresh tube. Two millilitres of a 14 per cent. sodium carbonate solution are added to the filtrate and the tube and its contents placed in boiling water for two minutes. The mixture is cooled and filtered into a standard glass cell. By means of a comparator into which the cell is placed, the colour of the liquid is compared with discs containing 1·5, 2·3 and 6·0 Lovibond units of blue. Any filtrate exhibiting over 2·3 units of blue has been improperly pasteurised.

When ice-cream is subjected to chemical examination, tests should always be made for preservatives and for traces of metals, such as zinc and lead, which have, from time to time been found in the product. Such traces of metals are usually due to contact with the containers. They may also gain access to the milk in the mix, from the churns in which the liquid has been conveyed.

LEGISLATIVE CONTROL

It is an unfortunate fact that the legislation which may be used to control the production and distribution of ice-cream is quite inadequate for its purpose. For the country as a whole, there are certain specific powers dealing with the question, and the little assistance which the Public Health administrator can obtain is far from adequate and much too indefinite in many instances. A list of these enactments is set out below in chronological order, together with the applicable sections or parts thereof. When the annual increasing output and consumption of ice-cream are borne in mind, such a position assumes the aspect of a dangerous anachronism, which should receive the urgent attention of those responsible for national legislation, and the advent of the Ice-Cream (Heat Treatment) Regulations, 1946, is welcomed as a major step forward.

Act or Order	Section or Article Applying
Public Health (Preservatives in Food) Regulations, 1925	4–6
Public Health (Infectious Disease) Regulations, 1927	10–11. Schedule 1 (Part 3)
Public Health Act, 1936	149
Factories Act, 1937	1–2–3–4–5–6–7–8–9–10–11–41–42–43–44–45
Food and Drugs Act, 1938	1–2–3–13–14–16–17–18–37–68–69–70
Ice-Cream (Heat Treatment) Regulations, 1946.	Whole Regulations.

All superfluous matter has been omitted from the following excerpts, only such Acts, Orders, or Sections, or parts thereof which are of use in controlling food supplies, including ice-cream manufacture and distribution, being indicated.

Public Health (Preservatives in Food) Regulations, 1925

Definitions.—"Food" means food or drink intended for human consumption.

"Sell" includes expose or offer for sale or deposit in any place for the purposes of sale, and "sale" shall be construed accordingly.

"Preservative" means any substance which is capable of inhibiting, retarding, or arresting the process of fermentation, acidification, or other decomposition of food or of masking any of the evidences of putrefaction, but does not include common salt, saltpetre, sugars, acetic acid or vinegar, glycerine, alcohol or potable spirits, herbs, hop extract, spices or essential oils used for flavouring purposes.

Certain amendments to these Regulations have been made by the Public Health (Preservatives in Food) Regulations, 1926 and 1927. The relevant amendments have been incorporated in the Articles set out below.

Prohibition of Use of Preservatives.—Article 4. (1) No person shall manufacture for sale or sell any article of food which contains any added preservative or any of the colouring matters specified in Part 2 of the First Schedule : Provided that :

(i) Any article of food specified in Part 1 of the Schedule may contain preservative of the nature and in the proportion therein specified ;

(ii) Where any article of food specified in Part 1 of the Schedule is used in the preparation of any other article of food, the latter article may contain any preservative necessarily introduced by the use of the former article, but the total proportion of any one preservative contained in any article of food specified in that Part of the Schedule shall not exceed the proportion therein specified.

Of the foods specified in the First Schedule, Part 1, no mention is made

of the fact that any milk products are exempt from the above subsection of Article 4. As regards colouring matter, annatto is not one of the prohibited colouring materials, and may therefore be used in the preparation of ice-cream.

Power of Entry.—Article 6. (1) Gives power of entry to any premises where articles to which the Regulations apply are prepared, packed, labelled, or stored.

Power to Take Samples—[2] Gives power to take samples of such articles or ingredients used in the preparation of such articles. Samples to be paid for if required.

Public Health (Infectious Diseases) Regulations, 1927

Definitions.—"Occupier" includes a person having the charge, management, or control of a building or part of a building in which the patient is, and in the case of a house the whole of which is let out in separate tenements, or in the case of a lodging house the whole of which is let to lodgers, the person receiving the rent payable by the tenants or lodgers either on his own account or as the agent of another person.

"Dysentery" includes amœbic and bacillary dysentery. "Enteric Fever" includes typhoid and paratyphoid fevers.

Prevention of Spread of Infection.—Article 10. Upon the receipt of a notification, or on becoming aware in any other way of a case or suspected case of Malaria, or Dysentery, in his district, the Medical Officer of Health, or an Officer of the Local Authority acting under the instructions of the Medical Officer of Health shall make such enquiries and take such steps as are necessary or desirable for investigating the source of infection, for preventing the spread of infection, and for removing conditions favourable to infection, and if no Medical Practitioner is in attendance on the patient, the Medical Officer of Health shall also take such steps as are necessary or desirable for ascertaining the nature of the case.

Duties of Medical Officer of Health.—Article 11. The duties of a Medical Officer of Health on becoming aware of a case or cases in his district of (i) Malaria, or (ii) Typhus Fever or Relapsing Fever, or (iii) Enteric Fever or Dysentery, shall, in addition to those set forth in Article 10 above, comprise the duties set forth in Parts 1, 2, and 3 of the First Schedule.

Part 3 of the First Schedule, which chiefly concerns the subject under review, is set out below.

First Schedule. Part 3

A.—ENTERIC FEVER AND DYSENTERY

(1) (i) In any case of enteric fever or dysentery occurring in his district of which the Medical Officer of Health becomes aware, and in connection with which he is of opinion after enquiry that such a course is necessary to prevent the spread of infection, he shall report accordingly to the Local Authority, who may by notice in writing require that, until a further notice in writing is given by them revoking the first-mentioned notice on the ground that the risk of infection is removed:

(a) The person specified in the notice shall discontinue any occupation connected with the preparation or handling of food or drink for human consumption.

(b) Suitable measures to be specified in the notice shall be taken with respect to cleansing, disinfection, disposal of excreta, destruction of flies, and prevention of contamination of articles of food or drink for human consumption.

(ii) The notice may be addressed to the head of the family to which the patient belongs, or to any person in charge of or in attendance on the patient, or to any other person in the building or place of which the patient is an inmate, or to the occupier of the building or place.

(2) (i) If a Medical Officer of Health has grounds for suspecting that any

person in the district who is employed in any trade or business concerned with the preparation or handling of food or drink for human consumption is a carrier of enteric fever or dysentery infection, he shall report accordingly to the Local Authority, who may give notice in writing to the responsible manager of the trade or business concerned certifying that for the purpose of preventing the spread of the disease they consider it necessary for their Medical Officer of Health or a Medical Officer acting on his behalf to make a medical examination of such suspected person, and the responsible manager and all other persons concerned shall give to the Medical Officer of Health all reasonable assistance in the matter.

(ii) If from the result of any such examination or from bacteriological or protozoological examination of material obtained at any such examination, or from any other evidence which he may deem sufficient for the purpose, the Medical Officer of Health is of the opinion that the specified person is a carrier of enteric fever or dysentery infection, the Medical Officer of Health shall report to the Local Authority who may give a notice in writing to that effect to the responsible manager and to the suspected person with a view to preventing, during a period to be specified in such notice, the employment of the person to whom the notice relates in the conduct of the trade or business, or in any other trade or business concerned with the preparation or handling of food or drink for human consumption.

Public Health Act, 1936

Section 149.—Any person knowing that he is suffering from a notifiable disease, engages in or carries on any trade, business or occupation in which he cannot engage in or carry on without risk of spreading the disease shall be liable to a fine not exceeding five pounds.

"Notifiable Disease" means any of the following diseases, namely, small-pox, cholera, diphtheria, membraneous croup, erysipelas, scarlet fever, typhus fever, typhoid and enteric fevers.

Factories Act, 1937

The conditions as to the control of food premises specified in Section 13 of the Food and Drugs Act, 1938, do not apply to any room coming within the terms of this Act. As many of the premises used for the production of ice-cream come within the Act, the relevant Sections dealing with the sanitary control of such premises are indicated.

Cleanliness.—Section 1. Every factory shall be kept in a clean state and free from effluvia arising from any drain, sanitary convenience, or nuisance. In addition:

(a) Accumulations of dirt and refuse shall be removed daily from floors and benches of workrooms and from staircases and passages.

(b) The floor of every workroom shall be cleaned at least once in every week by washing or, if effective or suitable, by sweeping or other method.

(c) All inside walls and ceilings of rooms, passages, and staircases shall—
  (i) if they have a smooth impervious surface be washed with hot water and soap, with suitable detergent or cleansed in a satisfactory manner every fourteen months;
  (ii) painted surfaces to be re-painted or varnished every seven years and washed down in a suitable manner every fourteen months; or,
  (iii) whitewashed or colourwashed once within every fourteen months.

The requirements as to cleansing set out above shall not apply to any factory where mechanical power is not employed or where less than ten persons are employed unless the Factory Inspector requires and if the requirements are inadequate, they may be varied on Order of the Secretary of State.

Overcrowding.—Section 2. (1) A factory shall not be so overcrowded as to cause risk of injury to the health of the persons employed therein.

(2) At least four hundred cubic feet per person shall be allowed otherwise the factory shall be deemed to be overcrowded.

(3) Provides exemption where suitable mechanical ventilation is employed when two hundred and fifty cubic feet shall be deemed sufficient. Certain exceptions are provided for.

(4) Regulations may be made for a factory or a part thereof increasing the number of cubic feet to be allowed for each person employed in a workroom.

(5) No space more than fourteen feet from the floor shall be taken into account when calculating cubic space.

(6) A notice must be posted in each room stating number of workpeople allowed in that room unless the Factory Inspector otherwise allows.

Temperature.—Section 3. (1) A reasonable temperature must be maintained in all workrooms.

(2) Where a substantial portion of the work is done sitting a temperature of less than sixty degrees shall not be deemed, after the first hour, to be a reasonable temperature. A suitable thermometer shall be provided in each workroom of this description.

(3) Secretary of State may prescribe a standard of reasonable temperature for any class of factory by means of Regulations.

Ventilation.—Section 4. (1) Efficient and suitable provision to be made for adequate ventilation together with the removal of fumes and dust.

(2) Secretary of State may make Regulations prescribing a standard of adequate ventilation for factories.

Lighting.—Section 5. (1) Efficient provision to be made for securing and maintaining sufficient and suitable lighting, both natural and artificial in every part of the factory where work is carried on.

(2) Secretary of State may make Regulations prescribing standard of lighting.

(4) All glazed windows and skylights shall be kept clean and free from obstructions both inside and out but may be whitewashed or shaded to mitigate heat and glare.

Drainage of Floors.—Section 6. Where any process is carried on where the floor is liable to be wet, efficient means of drainage shall be provided.

Sanitary Conveniences.—Section 7. (1) Sufficient and suitable sanitary conveniences shall be provided, maintained, and kept clean with provision for lighting with separate accommodation for each sex.

(2) Secretary of State may make Regulations prescribing what is considered to be suitable and sufficient provision.

The accommodation necessary is determined by the Sanitary Accommodation Order, which lays down the following standard:

(1) In factories where females are employed or in attendance, there shall be one sanitary convenience for every 25 females.

(2) In factories where males are employed or in attendance, there shall be one sanitary convenience for every 25 males, provided that if the number of males employed exceeds 100 and sufficient urinal accommodation is also provided, it is sufficient if there is one sanitary convenience for every 25 males up to the first 100, and one for every forty afterwards.

The Order also specifies measures required for the adequate care and upkeep of sanitary conveniences.

Sections 8, 9 and 10 deal with the enforcement by District Councils of the provisions of the foregoing Sections, with the powers of the Sanitary Inspector as to defects remediable by a District Council and with cases where the District Council may default. Section 11 deals with the medical supervision of the employees in certain cases.

Supply of Drinking Water—Section 41. (1) A suitable and sufficient supply of drinking water shall be maintained at easily accessible points.

(2) If a mains supply is not available or the water cannot be laid on, drinking water must be stored in suitable containers. All drinking water supplies shall be clearly labelled 'Drinking Water.'

Washing Facilities.—Section 42. Adequate and suitable facilities for washing including the provision of soap and towels or other suitable means of cleaning or drying must be provided in conveniently accessible positions and maintained in a clean state.

Accommodation for Clothing.—Section 43. Suitable cloakroom accommodation must be provided for the storage of outdoor clothing.

Facilities for Sitting.—Section 44. Sufficient seats to be provided for the use of female workers whose work is carried out standing.

First Aid.—Section 45. Suitable first aid equipment to be provided, additional equipment being necessary for every additional one hundred and fifty persons employed. The first aid equipment to be in the charge of a responsible person. In the case of factory where more than fifty persons are employed, the person in charge shall be trained in first aid work and a notice must be affixed in each room stating the name of the person in charge of that room.

Food and Drugs Act, 1938

Definitions: "Food" means any article used as food or drink for human consumption.

"Ice-cream" includes any similar commodity.

Addition of other substances to any food.—Section 1. No person shall add, or direct, or permit any other person to add any substance to food so as to render it injurious to health.

Section 2. Prohibits the abstraction of anything from an article of food so as to affect injuriously the nature, substance, or quality of the article.

Sale of Article.—Section 3. Provides that no person shall sell to the prejudice of the purchaser any article of food . . . which is not of the nature, substance or quality demanded by the purchaser.

Rooms where Food is prepared or stored.—Section 13. (1) Application to all rooms in which food for human consumption is prepared for sale, sold, offered or exposed for sale or deposited for the purpose of sale. Following conditions apply:

(a) No sanitary convenience, dustbin or ashpit shall be within or communicate directly with the room or be so placed that offensive odours therefrom can penetrate into the room.

(b) No cistern for the supply of water to the room shall be in direct communication with or discharge directly into a sanitary convenience and there shall not be within the room any outlet for the ventilation of a drain or, except with the approval of the Local Authority, an inlet into any drain conveying sewage or foul water.

(c) The walls, ceiling, floor, windows and doors of the room shall be kept in a proper state of repair.

(d) The walls, ceilings and doors of the room should be painted, limewashed, cleansed, or purified as often as may be necessary to keep them clean and the windows of the room shall be kept clean.

(e) The room shall not be used as a sleeping place and so far as may be necessary to prevent risk of infection or contamination of food in the room, no sleeping place adjoining the room shall communicate therewith except through the open air or through an intervening ventilated space.

(f) Except in the case of an artificially refrigerated room, suitable and sufficient means of ventilation shall be provided and suitable and sufficient ventilation shall be maintained.

(g) No refuse or filth whether solid or liquid shall be deposited or allowed to accumulate in the room except so far as may be necessary for the proper carrying on of the trade or business for which the room is used and the floor of the room shall be cleansed as often as may be necessary to keep it clean.

(h) Cleanliness shall be observed by persons employed in the room, both in regard to the room and all articles, apparatus, and utensils therein and in regard to themselves and their clothing.

(*i*) There shall be provided in, or within a reasonable distance of the room suitable washing basins and a sufficient supply of soap, clean towels and clean water both hot and cold, for the use of persons employed in the room.

(2) Provides for legal penalties.

(3) Owner responsible for any alterations required if let by him as room for the purpose of preparation, sale or storage of food.

(4) If the room was not let for this purpose, owner may recover expenses of alteration from occupier.

(5) Defines "room" as any shop, cellar or other part of a building, shed, store or outbuilding or any part thereof.

(6) Save as may be provided by Food Regulations, neither this nor the next succeeding Section shall apply in relation to premises which are used for the preparation, sale or storage of articles prepared from, or consisting of, materials other than those of animal or vegetable origin, but are not otherwise used for any purposes in connection with the preparation, storage or sale of food

In connection with the above Section, it is essential that all ice-cream manufacturing premises should bs up to first-class dairy standard, particularly when it is remembered that this commodity is consumed in its raw state, in many instances, and has not been subjected to any sterilising influence. In dealing with the small tradesman whose premises come within the terms of this Section, the building in which the ice-cream is manufactured for sale either by wholesale or retail should be of a permanent nature with a suitable area of yard paving surrounding same. Preferably, the building should have two compartments, one of which is used for manufacture and storage, with the other for washing and sterilisation of utensils. If ice-cream is manufactured for retail sale by small shopkeepers, the premises should be suitable and maintained in a clean and satisfactory condition while, in addition, an electric or gas-operated refrigerator should be installed in the shop, no trade or business carried on which is likely to contaminate the ice-cream, and, as facilities are not likely to exist for the pasteurisation of the mix, a "cold mix" may be allowed always provided that sterilised milk is employed and that the mixture is placed within the refrigerator without delay and stored there.

Registration of Ice-cream Premises.—Section 14. (1) Subject to the provisions of this Section and of subsection (6) of Section 13, no premises shall be used for the sale or manufacture for the purpose of sale of ice-cream or the storage of ice-cream intended for sale . . . unless they are registered under this Section for that purpose by the Local Authority. Any person using any premises in contravention of the provisions of this subsection is guilty of an offence.

A certain amount of confusion exists amongst many manufacturers of ice-cream about the term "licence." No licence is necessary to produce ice-cream, but the premises must be *registered* with the Local Authority.

(3) If the Local Authority are of the opinion that any premises for which application to be registered is made or which are already registered under this Section, do not satisfy the requirements of the last preceding Section (13) or are otherwise unsuitable for use for the purpose for which they are proposed to be used or are being used, the Authority shall serve on the applicant for registration or the occupier for the time being of the premises, a notice stating the time and place, not being less than seven days after the date of the service of the notice, at which they propose to take the matter into consideration and informing him that he may attend before them and call witnesses on his behalf, at the time and place mentioned, to show cause why the Authority should not, for reasons specified in the notice, refuse the application or cancel the registration of the premises.

(4) If the person upon whom the notice is served fails to satisfy the Local Authority, they may refuse the application or cancel the registration. Notice

must be immediately given to the person affected and if he so desires within fourteen days of the Authority's decision, they shall give him within forty-eight hours, a statement of the grounds upon which their decision is based.

(5) An aggrieved person may appeal to court of summary jurisdiction.

(6) Any change of occupation of the premises shall be notified to the Local Authority by the incoming occupier.

(7) This Section does not apply to clubs, hotels, inns or restaurants and as regards premises used as theatres, cinemas, music or concert halls it shall have effect as if in Subsection (1) the words "the sale, or" and the words "or the storage of ice-cream intended for sale" were omitted.

(8) This Section does not apply in those districts where local powers already exist for the registration of ice-cream premises until that district, on the application of the Local Authority declares it to be in force therein.

Notices to be displayed by persons selling Ice-cream.—Section 16 (1). Every dealer in ice-cream who in a street or other place of public resort sells, or offers or exposes for sale, ice-cream from a stall, or from a cart, barrow or other vehicle or from a basket, pail, tray or other container used without a stall or vehicle, shall have his name and address legibly and conspicuously displayed on the stall, vehicle or container. Penalty for failure to do this is provided.

This Section does not apply to milk.

Notification of Cases of Food Poisoning.—Section 17. Provides for the notification of all cases of actual or suspected cases of food poisoning by registered medical practitioners to the Local Authority. The notification must state name, age and sex of patient and his address and state particulars of actual or suspected food poisoning.

Provisions as to Suspected Food.—Section 18. (1) If the Medical Officer of Health or other officer of the Local Authority has obtained a sample of the suspected food, notice may be given to the person in charge of such food that, until investigations are completed, the food or any specified part of same must not be used for human consumption and must not be removed except to a specified place. Provides penalty for contravention of this Order.

(2) If the investigations show that the food or part of same is likely to cause food poisoning it may be condemned or seized. If it may be safely used for human consumption, the detention order may be withdrawn.

(3) If the Order is withdrawn, or the food is not condemned, the Local Authority shall compensate the owner of the food to which the Order related for any depreciation in value as a result of the action taken by the Medical Officer of Health.

Provisions as to Ice-cream likely to cause Milk-borne Disease.—Section 37. (1) If any milk-borne disease occurs among persons living or working in or about premises on which ice-cream is manufactured, stored or sold, every manufacturer or dealer in ice-cream shall give notice to the Medical Officer of the district. Penalty provided for contravention.

(2) If the Medical Officer of Health has any grounds for suspecting that any ice-cream or substance used in its manufacture is likely to cause milk-borne disease, he may give notice to the person in charge thereof that, until further notice, the ice-cream or the substance in question or any portion thereof, is not to be used for human consumption and must not be removed except to a specified place. Penalty provided for contravention.

(3) If further investigation reveals that the ice-cream or the specified substance may be safely used for human consumption, the notice may be withdrawn, or if the Medical Officer is satisfied that it cannot safely be used, it must be destroyed.

(4) Provides for compensation for depreciation of the ice-cream or the specified substance when action has been taken if the notice is withdrawn or the ice-cream or substance is destroyed. No compensation is payable if the Local Authority prove that the ice-cream or substance was likely to cause milk-borne disease, if any ice-cream or substance was manufactured on or brought within any premises while a notice under subsection (2) was operative or where the owner of the ice-cream or the substance has failed to notify any milk-borne disease under subsection (1). The value of the ice-cream or substance concerned

must not be assessed at a sum greater than the cost incurred by the owner in making or purchasing it.

The term "milk-borne disease" means any of the following diseases:

(*a*) Enteric fever (including typhoid and paratyphoid fevers).
(*b*) Dysentery.
(*c*) Diphtheria.
(*d*) Scarlet fever.
(*e*) Acute inflammation of the throat.
(*f*) Gastro-enteritis.
(*g*) Undulant fever.

The Minister may, by Order, declare other diseases to be milk-borne diseases for the purposes of this Section.

Sampling.—Section 68. (1) An authorised officer of a Food and Drugs Authority or of a Local Authority which is not a Food and Drugs Authority may obtain samples for bacteriological and other examination.

(2) A sampling officer may purchase samples of any food or drug.

It should be noted that a sampling officer *may* either purchase or take samples without purchase within the terms of this Section. It is important also that an officer should be authorised to obtain samples for bacteriological examination in order that laboratory control may be fully exercised.

(4) A sampling officer may take samples of any food or substance capable of being used in the preparation of food, found on premises which he has entered in the execution of his duties under the Act.

(7) A sampling officer may, at the request or with the consent of the purchaser, consignee, or consumer, take at the place of delivery samples of any food other than milk delivered or about to be delivered, to the purchaser, consignee, or consumer in pursuance of a contract for the sale thereof to him.

Right to have Samples Analysed.—Section 69. Gives the sampling officer the right to have samples analysed. Other persons who have purchased any food may submit a sample of it to be analysed by the public analyst for the area in which the purchase was made. The public analyst must analyse it as soon as practicable and give a certificate in the prescribed form to the person by whom the sample was submitted.

Division of Samples.—Section 70. Any person purchasing a sample of any food which is to be analysed by the public analyst shall, after the purchase has been completed or the sample taken, inform the seller or his agent, the occupier of the premises or the person in charge thereof, of his intention to have the sample analysed by the public analyst. The sample must be divided into three parts, each part being marked and sealed or fastened up and, if required to do so, shall deliver one part to the vendor or his agent, retain one part for future comparison, and if the analysis is to be made, submit the remaining portion to the public analyst.

(2) Samples taken in transit or at the place of delivery to the purchaser shall be dealt with as set out above except that the first mentioned part of the sample shall be retained by the sampling officer unless the name and address of the consignor appear on the container in which case that part of the sample shall be forwarded by registered post to the consignor together with a notice stating that he intends to have the sample analysed by the public analyst.

Ice-Cream (Heat Treatment) Regulations, 1947

These Regulations, which came into force in May, 1947, require the heat treatment of all materials used in the manufacture of ice-cream and it should be noted that no exemption is provided for such materials when used for ice-cream production in hotels, restaurants, cinemas, clubs, and similar institutions, although, at the present time, no registration is required for such premises. So far as these Regulations are concerned, all premises where ice-cream is manufactured will now come under supervision.

Definitions: "Ice-cream" includes water ices, and any article, under whatever description it is sold, which is so similar to ice-cream as to constitute a substitute therefor.

"Ingredients" includes sugar and dried egg, but does not include colouring or flavouring materials or fruit, nuts, chocolate, and other similar substances.

"Complete cold mix powder" means a product which is capable of manufacture into ice-cream with the addition of water only, is sent out by the manufacturer in airtight containers, and has been made by evaporating a liquid mixture which has already been submitted to heat treatment comparable with that prescribed in these Regulations.

The Regulations set out the following requirements which must be observed in the sale of *all* ice-cream intended for sale for human consumption :

(1) When a complete cold mix is used which is reconstituted with wholesome drinking water and to which nothing is added other than colouring or flavouring materials, fruit, nuts, chocolate, or other similar substances, the reconstituted powder shall be converted into ice-cream within one hour of reconstitution.

(2) In any other case after the ingredients have been mixed together, the following provisions apply :

(a) The mixture shall not be kept for more than one hour at any temperature which exceeds 45° F. before being subjected to heat treatment as set out below.

(b) The mixture shall be heat-treated by being subjected to a temperature of not less than 150° F. for thirty minutes or to a temperature of not less than 160° F. for ten minutes.

(c) After the mixture has been subjected to heat treatment as set out above, it shall be reduced to a temperature of not more than 45° F. within one and a half hours and shall be retained at this temperature until it is frozen.

(d) Such indicating and recording thermometers shall be installed as required by the local authority for indicating and recording the temperatures to which ice-cream is raised, kept or reduced.

This part of the Regulations is not to come into operation until a date to be appointed by the Minister.

(e) All temperature records must be preserved for not less than one month.

(f) All apparatus to be installed, maintained and operated to the satisfaction of the local authority.

(3) When ice-cream has been frozen in course of manufacture, it shall not be sold or offered for sale unless either :

(a) It has been kept at a temperature not exceeding 28° F. since manufacture, or

(b) If its temperature has risen above 28° F. at any time since manufacture, it has been subjected to the heat treatment prescribed above and after having again been frozen, it has been kept at a temperature not exceeding 28° F.

(4) Ice-cream shall be protected from all forms of contamination during manufacture, storage and distribution and all apparatus employed shall be thoroughly cleansed immediately after use and kept clean at all times.

(5) Provides penalties for non-compliance with these Regulations.

(6) Gives power for enforcing and executing these Regulations.

(7) The authorities for enforcing and executing these Regulations are local authorities within the meaning of Section 64 of the Food and Drugs Act, 1938.

Apart from the Preservatives in Food Regulations, 1925 and 1927, there are no statutory regulations dealing with the chemical constitution of ice-cream.

Owing to the fact that, at one time, there was no legislation specifically assisting the Public Health administrator in dealing with the control of ice-cream production and distribution, a number of Local Authorities

obtained Parliamentary powers in their own Acts with the object of affording more complete control over the problem. This procedure, so far as it has obtained, has proved highly successful. Where the appropriate powers have been procured, particularly as regard refusal of registration, it has been found that the majority of manufacturers and retailers are only too willing to ensure that their methods of manufacture and sale are such as will satisfy all reasonable requirements. These powers of registration have now been superseded by those made available in Section 14 of the Food and Drugs Act, 1938. They do not, however, apply to those districts where local powers were in force at the passing of this Act unless the Local Authority of a district possessing such powers declares this particular Section to be in force in their area.

Foremost among Local Authorities which sought powers to control the production and sale of ice-cream was the London County Council. This Authority obtained such powers in several Acts of Parliament which were, with minor alterations, accepted as a pattern by other Local Authorities in the drafting of specific Sections in their own private Acts. The powers given to the London County Council were contained in the London County Council (General Powers) Acts, 1902 and 1908, which were similar to those set out in Sections 13 and 16 of the Food and Drugs Act, 1938. The London County Council (General Powers) Act, 1932, Section 5 of which deals with the registration of ice-cream premises, is set out below.

London County Council (General Powers) Act, 1932

Registration of Ice-cream Premises.—Section 5 (1) Any premises in the district of any sanitary authority used or proposed to be used—

(i) For the sale or the manufacture for the purpose of sale of ice-cream or other similar commodity; or

(ii) The storage of ice-cream or other similar commodity intended for sale; shall be registered by the owner or occupier or intending occupier thereof with the sanitary authority.

Premises registered pursuant to Section 29 of the L.C.C. (General Powers) Act, 1928, for any of the purposes mentioned in that Section (registration of premises used for manufacture of ice-cream, etc.), are deemed to be registered under this Section.

Penalty.—(2) Provides penalty for non-compliance.

Refusal of Registration.—(3) If a sanitary authority are satisfied that any premises registered or sought to be registered with them pursuant to this Section are unsuitable for the purpose for which they are registered or sought to be registered they may serve upon

(a) The person on whose application the premises were registered or the occupier of the premises; or

(b) The person applying for such registration (as the case may be) a notice to appear before them not less than seven days after the date of the notice to show cause why the sanitary authority should not for reasons to be specified in the notice refuse to register the premises or remove the premises from the register (as the case may be) and if he fails to show cause to their satisfaction accordingly they may refuse to register the premises or remove the premises from the register as the case may be.

Appeal against Refusal.—(4) Provides for an appeal by the aggrieved party against refusal to register or removal of premises from register.

Further Appeal.—(5) Provides for further appeal by the aggrieved party.

Removal from Register.—(6) Provides that no person may be removed from the register until the appeal has been heard.

Repeal.—(9) Section 29 of the L.C.C. (General Powers) Act, 1928, which deals with the registration of premises used for the manufacture of ice-cream is repealed.

Power to make Bye-laws.—Section 6. Gives power to make bye-laws for promoting sanitary and cleanly conditions in the manufacture, preparation, transport, storage, and exposure for sale of any article intended to be sold for food. Bye-laws made under this Section are to be enforced by the Borough Councils in accordance with Section 9 of the Act. Before any bye-laws are confirmed as regards any business carried on in any factory or workshop to which the Factory and Workshops Acts, 1901 to 1929, apply, the Minister of Health is required to consult the Secretary of State.

No bye-laws under this Section have been made or put into operation.

Power of Entry.—Section 10. This Section provides power of entry for all purposes of this Act.

Several other private Acts dealing with the sale of ice-cream are set out below.

Bristol Corporation Act, 1905

Prevention of Contamination of Ice-Cream.—Section 38 (1) Any person being a manufacturer or vendor of or merchant or dealer in ice-cream or other similar commodity who within the city—

(*a*) Causes or permits ice-cream or any similar commodity or any materials used in the manufacture thereof to be manufactured, sold, or stored in any room, cellar, or place which is in a condition likely to render such commodity injurious to health or in which there is an inlet or opening to a drain; or

(*b*) In the manufacture, sale, or storage of any such commodity does any act or thing likely to expose such commodity to infection or contamination or omits to take any proper precaution for the due protection of such commodity from infection or contamination; or

(*c*) Omits on the outbreak of any infectious disease amongst the persons employed in his business to give notice thereof forthwith to the Medical Officer ; shall be liable for every such offence on summary conviction to a penalty not exceeding forty shillings.

Name and Address on Vehicle.—Section 40. Every dealer in ice-cream or other similar commodity vending his wares from any cart, barrow or other vehicle or stand shall have his name and address legibly painted or inscribed on such cart, barrow, or stand and if he fails to comply with this enactment he shall be liable to a penalty not exceeding forty shillings.

Bristol Corporation Act, 1926

Registration of Premises.—Section 100 (1) Any premises used or proposed to be used for—

(*b*) The manufacture or sale of ice-cream shall be registered by the owner or the occupier thereof with the Corporation from time to time and no premises shall be used for the purposes aforesaid or any of them unless the same are registered as aforesaid.

Penalty.—(2) Any person offending against the provisions of this Section shall be liable to a penalty not exceeding forty shillings and to a daily penalty not exceeding twenty shillings.

Aberdare Urban District Council Act, 1927

Notification of Infectious Disease.—Section 98 (1) Any person being a manufacturer or vendor of or merchant or dealer in ice-cream or other similar commodity who within the district omits on the outbreak of any infectious disease amongst the persons employed in his business or residing in any premises which are used by him for the manufacture of ice-cream or other similar commodity to give notice thereof to the Medical Officer shall be liable for every such offence to a penalty not exceeding forty shillings.

Seizure of Ice-cream following Outbreak of Infectious Disease.—(2) In the event of any persons so employed or resident suffering from any infectious disease the Medical Officer or the Sanitary Inspector or any other officer who is duly authorised by the Council in that behalf may seize and destroy all ice-cream or similar commodity or materials for the manufacture of same in any of the

premises and the Council shall compensate the owner of the ice-cream or similar commodity or materials so destroyed. Provided that no compensation shall be payable in respect of any ice-cream or similar commodity or materials for the manufacture of the same manufactured or brought upon the said premises after such seizure and while any person is suffering from infectious disease.

Name and Address on Vehicle and Container.—(3) Every vendor of or dealer in ice-cream or other similar commodity vending his wares from any cart barrow or other vehicle or stand or from a pail container or similar receptacle used without a cart barrow or other vehicle shall have his name and address legibly painted or inscribed on such cart barrow vehicle or stand pail container or receptacle and any person who shall fail to comply with this subsection shall be liable to a penalty not exceeding forty shillings.

Powers to Inspect Materials and Product.—(4) The Medical Officer and the Sanitary Inspector and any other officer duly authorised by the Council in that behalf shall at all reasonable times have the same power of inspection of the materials or commodities or articles of food in the premises of any manufacturer or vendor of or merchant or dealer in ice-cream or other similar commodity and of any cart barrow vehicle or stand pail container or receptacle in, from, or on which the same are offered for sale as an officer of the Council would have under Section 12 of the Public Health Act, 1925 (now Section 13 of the Food and Drugs Act, 1938) in the cases therein mentioned and any person refusing inspection of the materials or commodities or articles of food in any such premises or obstructing such officer as aforesaid in the execution of his duty shall be liable to a penalty not exceeding five pounds.

Essex County Council Act, 1933

Section 158 of this Act requires a vendor of ice-cream to be registered with the Local Authority. Any unsuitable premises can be considered by the Local Authority and the vendor can appear before them to show cause why he should be registered or why his name should not be removed from the register. Right of appeal is provided.

Rhyl Urban District Council Act, 1935

Premises and Persons to be Registered.—Section 100 (1) (a) Any person being a manufacturer or vendor of or dealer in ice-cream; and

(b) Any premises within the district used or proposed to be used for the manufacture for sale or sale of ice-cream;.................................. shall be registered with the Council in the case of any such premises by the owner or occupier or intending owner or occupier thereof.

Persons to be Registered.—(2) (a) No person shall carry on the business of a manufacturer or vendor of or dealer in ice-cream . . . within the district unless he is registered as aforesaid.

(b) No premises within the district shall be used for the manufacture for sale or sale of ice-cream . . . unless such premises are so registered as aforesaid.

Penalty.—(3) Provides penalties for contravention of this Section.

Refusal or Revocation of Registration.—(4) (a) The Council may refuse to register any such person or premises as is or are referred to in subsection (1) of this Section or (after giving one month's notice in writing to the person registered) revoke the registration of any such person or premises on the ground (as regards any person) that the public health is or is likely to be endangered by any act or default of such person in relation to the quality, storage, or distribution of the ice-cream . . . and (as regards premises) that such premises are not suitable to be used for the purposes aforesaid:

Provided that before refusing or revoking such registration the Council shall serve upon the applicant for registration or upon the person registered or in whose name such premises are registered a notice to appear before them not less than seven days after the date of the notice to show cause why the Council should not for reasons to be specified in the notice refuse to register or revoke the registration of the person or premises.

Grounds of Refusal to be Stated.—(b) If the Council refuse to register or revoke the registration of any such person or premises they shall deliver to the person applying for such registration or to the person registered or in whose

name the premises are registered a statement in writing of the ground or grounds upon which such refusal or revocation is based. Notice of the right of appeal next hereinafter mentioned shall be endorsed on every such notice.

Appeals.—(c) Provides for appeal by aggrieved person.

(*d*) Person appealing to give written notice of such appeal and grounds thereof.

(*e*) Court may confirm Council's refusal or revocation or may order that the person or premises be registered.

Definition.—(5) Defines "ice-cream" as including any similar commodity.

Section 101, subsections 1, 2, and 3 of this Act are similar in every respect to Section 98, subsections 1, 2, and 4 of the Aberdare Urban District Council Act, 1927, previously described.

The provisions of Section 136 of the Maidstone Corporation Act, 1923, deal with prevention of contamination, notification of infectious disease, name and address on vehicle, inspection of materials and of product. All these have already been described in the Acts previously indicated. In addition to the above, the Torquay Corporation Act, 1923, contains powers relating to ice-cream control similar to those which are embodied in the Maidstone Corporation Act previously specified.

The following private Acts also contain powers intended to deal with food premises, ice-cream being specifically mentioned in certain cases.

Nuneaton Corporation Act, 1921

Ice-cream premises have to be registered.

Nottingham Corporation Act, 1923

Embodies powers similar to those which were incorporated in the London County Council (General Powers) Acts, 1902 and 1908. The Corporation is empowered to make bye-laws for promoting and securing cleanly conditions in the manufacture, storage, transport, or exposure for sale of any article intended for the food of man.

Birmingham Corporation Act, 1914

Section 33 requires that premises where food is prepared and manufactured for sale shall be registered. This Section did not apply to factories which came within the provisions of the Factories and Workshops Act, 1901.

Liverpool Corporation Act, 1921

This Act embodies provisions similar to those which were contained in the London County Council (General Powers) Act, 1908. Bye-laws may be made for preventing contamination of food and for controlling food premises. The manufacture, sale, or storage of ice-cream in unsuitable premises is prohibited.

Glasgow Police Act, 1866

Section 269 provides penalty for lack of cleanliness in premises where food is sold.

The fact need scarcely be stressed that, while large Corporations could easily promote private Acts, smaller Authorities were by no means placed in such a happy position.

Suggestions for Efficient Control

As already indicated, the existing legislation provided to deal with the registration of ice-cream manufacturing and retail premises and wi h the handling of the product, while much improved by the advent of the Food and Drugs Act, 1938, is by no means sufficient for its purpose, no assurance being given that all ice-cream is produced under satisfactory conditions or, more particularly, that the finished commodity is in all cases of reasonable

purity and wholesomeness. When the results of bacteriological and chemical examinations are considered (see Tables 3 to 5 set out below), it will be further evident that some additional measure of control is a matter of extreme urgency. In addition, quite apart from any bacterial excess, detritus, blood, pus, and other impurities have been found in ice-cream.

TABLE 3

No. of sample	Total bacterial count per ml.	Bacillus coli present in :
1	375,000	0·1 ml.
2	1,120,000	0·1 ml.
3	2,080,000	1·0 ml.
4	1,182,000	0·001 ml.
5	1,760,000	0·00001 ml.
6	60,400	0·0001 ml.
7	310,000	1·0 ml.
8	1,600,000	0·01 ml.
9	117,600	0·0001 ml.
10	Several millions	0·001 ml.
11	6,800,000	0·0001 ml.
12	166,000	0·1 ml.
13	2,230,000	0·00001 ml.
14	57,000	0·0001 ml.

No gelatine was present in any of the above samples, which were chiefly obtained from small vendors.

Benson has given the following figures illustrating the result of a representative number of bacteriological examinations of ice-cream.

TABLE 4

No. of samples	Bacteria under 30,000 per ml. Per cent.	Bacteria under 100,000 per ml. Per cent.	Bacteria under 200,000 per ml. Per cent.	Bacteria over 200,000 per ml. Per cent.
62	17 or 27	32 or 52	45 or 73	17 or 27
45	23 or 51	37 or 82	42 or 93	3 or 7

In the 62 samples, *Bacillus coli* was absent in 38 or 61 per cent., and present in 24 or 31 per cent. In the 45 samples, *Bacillus coli* was absent in 23 or 51 per cent., and present in 22 or 49 per cent. Of the total number of samples, the highest bacterial count was 5,076,000, while the lowest was 800 bacteria per cubic centimetre.

TABLE 5

Sample No.	Analysis				Remarks
	Milk Per cent.	Sugar Per cent.	Starch Per cent.	Water Per cent.	
1	40	10	10	40	No preservatives
2	70–80	20–30	—	—	do.
3	20	14	10	56	do.
4	26	12	10	52	do.
5	57	11	11	21	do. Traces of colouring matter and flavouring materials.
6	38	10	12	40	No preservatives
7	79	21	—	—	do.
8	84	10	6	—	do.
9	85	10	5	—	do.
10	84	10	6	—	do.
11	83	10	7	—	do.
12	84	8	8	—	do.

F

With the exception of samples 2 and 7, all contained starchy matter presumed to be cornflour or other cereal filling introduced in ice-cream powders. No gelatine was present in any of the samples.

Benson reports that, in eleven samples of ice-cream examined for butter-fat, the lowest percentage was 3·1 per cent., while the highest wa   · per cent.

The following methods of controlling food supplies are used in various other countries, and are illuminating. As will be seen, such regulations deal mainly with the bacterial content of the product.

Australia

Regulations are in force dealing with:

(1) Construction of premises.
(2) Cleanliness of premises.
(3) Wrapping and packing of food.
(4) Personal cleanliness and freedom from disease.
(5) Carriage and transport of food.

These regulations apply to *all* food-preparing premises. The regulations in force which deal solely with ice-cream are:

(a) Walls, floors, and ceilings of premises must be properly constructed, with adequate light and ventilation and protection from flies.

(b) Ice-cream must not be manufactured, sold, or stored in any dwelling-room, or in any room communicating directly with a privy, w.c., stable, or sleeping-room, or any room having an opening communicating directly with any drain or sewer.

(c) Ice-cream and ices must not be manufactured, stored, or deposited in any open shed or unenclosed place.

(d) All receptacles must be suitably cleansed and protected from dust, flies, and contamination.

(e) Once used, packages made wholly or in part of wood, paper, or other absorbent material must not be refilled.

(f) Re-freezing of the product is prohibited.

(g) No person engaged in the manufacture or sale of ice-cream must allow his hands or any part of his person to come into contact with ice-cream or ices intended for sale.

(h) Milk or cream employed in manufacture must be kept at a temperature below 50° F.

The last condition applies to Tasmania only.

The bacterial standards fixed are:

(1) AUSTRALIA.—The total count must not exceed 250,000 organisms per millilitre. No *Bacillus coli* or other pathogenic organisms must be present, while the product must contain at least 12 per cent. of milk-fat.

(2) QUEENSLAND.—This province possesses its own standards. Total count must not exceed 50,000 bacteria per millilitre. No *Bacillus coli* or other pathogenic organisms must be present.

(3) TASMANIA.—Ice-cream must not contain more than 500,000 bacteria per millilitre. No mention is made of the *Bacillus coli* content. The product must contain 10 per cent. of butter-fat in the form of cream.

Canada

Ordinary ice-cream must not contain:

(a) Less than 13 per cent. milk-fat.
(b) Less than 36 per cent. good solids.
(c) More than ½ per cent. stabiliser.
(d) Less than $1\frac{9}{10}$ lb. food solids per gallon, not less than 0·65 lb. to be milk-fat.
(e) Any fat other than milk-fat.

Fancy ices are allowed a legal minimum of 11 per cent. milk-fat.

United States

Regulations are in force controlling the manufacture and sale of ice-cream, and specifying the measures necessary to ensure protection from contamination and disease. These regulations closely resemble those in force in Australia. The bacteriological standards are:

				Maximum bacterial count per ml.
California	.	.	.	. 150,000
Connecticut	.	.	.	. 100,000
Michigan	.	.	.	. 150,000
Iowa	.	.	.	. 250,000

No mention is made of the *Bacillus coli* content.

In New York City, ice-cream must contain not less than 10 per cent. milk-fat with a total solids content of not less than 18 per cent. (see page 4).

New Zealand

Regulations similar to those in force in Australia control the manufacture, sale, and distribution of ice-cream, which must not contain more than 50,000 organisms per millilitre when sold. No definite mention is made of the *Bacillus coli* content, but it is stated that no harmful or pathogenic organisms shall be present.

Isle of Man

When examined within twenty-four hours of the sample being taken in liquid form it shall not contain more than 100,000 bacteria per millilitre, while no *Bacillus coli* shall be present in one-tenth of a millilitre. Ice-cream must contain not less than 8 per cent. of milk-fat with a total solids content of 30 per cent. or more.

Holland

Certain decrees are in force, dealing with the supervision and manufacture of all food intended for human consumption, together with the prohibition of the use of deleterious materials and utensils. The maximum bacterial content of ice-cream allowed is 100,000 organisms per millilitre, and *Bacillus coli* must be absent, while the milk-fat content must not be less than 11 per cent.

Northern Ireland

Regulations made under the Sale of Ice-cream Act, 1937, of Northern Ireland require that no ice-cream shall contain more than 200,000 organisms per millilitre and that *Bacillus coli* shall not be present in 1 ml. of the product. In addition, a standard of not less than 5 per cent. of milk-fat has been fixed while the total solids must not be less than 30 per cent. of the whole.

Belgium

The legislation dealing with foodstuffs are similar to those in force in Holland. Bacterial standards for ice-cream have been fixed by the Municipality of Ghent. In this case, the total count must not exceed 5,000 bacteria per millilitre, amongst which there must be no liquifying colonies, intestinal or pathogenic organisms.

From the foregoing it will be seen that considerable variation exists in the bacterial standard demanded in various parts of the world. The total permissible count varies within the broadest of limits, while some countries make no mention whatever of the *Bacillus coli* content in their legislation. It is, however, apparent that Great Britain lags quite a considerable distance behind many other countries in the steps taken to protect ice-cream from contamination, and the consumer from dangerous infection. The following paragraphs, therefore, contain suggestions as to the powers which should be provided for this purpose in any future legislation.

The suggestions have been grouped into sections, as follows:

(1) Premises.
(2) Personnel.
(3) Materials.
(4) Bacteriological Standard.
(5) Chemical Standard.
(6) Distribution.

(1) Premises.—The premises in which ice-cream is prepared, stored, or sold require to be registered, but it is essential that such registration should be renewable at annual intervals.

At the present time, exemption from registration is given to hotels, restaurants, cinemas, clubs, and similar institutions and this anomaly should be rectified without delay. The kitchens at these establishments where ice-cream is generally prepared cannot be said to be suitable for the production of this foodstuff, particularly when it is remembered that vegetables are cleaned and dirty utensils washed, often in the same room as that in which manufacture takes place. It should be noted that, although such premises are exempt from registration, the ice-cream produced therein must comply with the provisions of the Ice-Cream (Heat Treatment) Regulations, 1947.

The premises should comply with the following conditions which should be prescribed by law:

(a) *Construction.*—Floors to be constructed of impervious material and be well drained. Walls to have smooth impervious surfaces. Ceilings to have smooth, easily-cleansed surfaces. Sufficient and suitable natural and artificial lighting, together with adequate ventilation, to be provided (definite standards should here be prescribed). Sinks of suitable type with satisfactory drainage arrangements, wash-basins (one to each ten employees), with sufficient supplies of hot and cold water and a sufficient supply of clean towels, soap, and nail brushes, to be provided for the workers. The external yard to be properly paved and drained.

(b) Premises, outbuildings, yards, and sheds to be maintained in a cleanly condition, free from rubbish and other offensive matter.

(c) Floors to be cleansed daily, walls weekly, and ceilings quarterly.

(d) Ice-cream not to be prepared, packed, or stored, or sold in any room or place

  (i) which contains or communicates directly with a sanitary convenience;
  (ii) which is used as or which adjoins a sleeping-room;
  (iii) which is used as or adjoins a living-room;
  (iv) in which is situated an outlet for the ventilation of a drain or any inlet to a drain, whether trapped or not.

(e) Impervious refuse receptacles with properly fitted lids to be placed in a suitable situation, some distance away from the buildings. Refuse receptacles to be emptied and cleansed daily.

(f) Fittings, apparatus, instruments, and receptacles to be cleansed daily. Means of cleansing and steam sterilisation to be provided.

(g) Precautions to be taken to prevent the ingress of rats, mice, and other vermin or insects.

(h) Foodstuffs to be protected from dust, dirt, and offensive odours at all stages of manufacture.

(2) Personnel.—It is equally important that persons as well as premises should be registered, and the Local Authority should have power to refuse such registration to any person or to remove any person from the register. Registration certificates should be renewed annually. The following rules regarding the conduct of personnel should be strictly enforced:

(a) Clean white suits and caps to be worn by all persons working in manufacturing premises.

(b) Employees to be required to wash their hands before commencing work and after work has been completed, and also at such times as may be necessary during working hours. Finger-nails to be kept clean at all times and bodily cleanliness to be considered essential.

(c) Spitting, smoking, and chewing tobacco during working hours to be prohibited.

(d) Compulsory notification of *all* infectious or skin diseases occurring amongst any persons engaged in the manufacture or distribution of ice-cream to be enforced.

(e) No employee to allow his hands or any portion of his person to come into contact with the product.

It would be advisable if all employees were required to undergo a comprehensive medical examination at frequent intervals.

(3) Materials.—The materials used and their treatment are important, especially as the process of pasteurisation, together with the addition of colouring matters or flavours, may cover up original deficiencies in raw materials.

There can be little doubt that fresh dairy products, i.e. milk, cream, butter, and eggs, make the best ice-cream. While ice-cream manufactured from other ingredients may be satisfactory, wholesome, nourishing, and palatable, it will not bear comparison with a product produced from milk and cream, particularly as regards flavour, although, at the present time, the use of most milk products is prohibited. For this reason, it might be wise to distinguish the various types of permitted ice-creams by appropriate statutory nomenclature (see also page 78). The addition of colouring matters, apart from fresh fruit or fresh fruit juices, should be prohibited. Gelatine, if used, should be of the highest quality, being preferably purchased on the basis of bacterial condition, while the addition of more than 1 per cent. of this or any other stabilising substance should not be permitted. A standard specifying the ingredients which may be used is an urgent necessity.

The materials should be stored in a clean place, separated from the room or rooms in which the product is manufactured, and should remain in sealed containers until required for use. It is particularly important that milk, cream, and other perishable articles used during manufacture should be maintained at a temperature not exceeding 45° F. prior to use. The milk or cream should possess a total bacterial count of not more than 200,000 organisms per millilitre (Disc 6, Category A, of the Resazurin Test), with *Bacillus coli* absent in 0·01 ml. before being mixed with the other ingredients. Its acidity prior to use should never exceed 0·20 per cent. Plastic cream

may be stored successfully, when chilled, for lengthy periods.   This is produced by a special separator and contains 70 to 80 per cent. butter-fat. It may be stored in wood or pulp containers.   Unsalted butter used in the production of emulsified cream for ice-cream manufacture should be stored at zero temperature, otherwise moulds may develop and injure the flavour, particularly if the store is damp.   Dried eggs if stored for lengthy periods will become rancid and undergo flavour changes, while milk powders should possess a low moisture content and be stored in a dry place.

In the event of any outbreak of infectious disease occurring on premises where ice-cream is produced or sold, or among employees, the product should be destroyed, together with all raw materials which might have been contaminated.   In such cases, compensation should be paid.

In addition, wholesale manufacturers of ice-cream should be required to keep records of the names and addresses of all persons purchasing ice-cream from them for retail sale while factories producing ice-cream powders should require to be registered and records showing the names and addresses of all persons purchasing such powders for manufacturing purposes should be kept.

(4) Bacteriological Standard.—However suitable the suggested bacterial grading may turn out to be as a temporary measure, this will not provide guaranteed freedom from pathogenic organisms which may obtain entrance to the ice-cream after production or during distribution.   Any standard should, however, prove that high-grade materials have been used and that the mix has been efficiently processed, and for this reason, one which can be legally enforced is highly desirable.   Such a standard should fix a total bacterial count not exceeding 50,000 organisms per millilitre, with *Bacillus coli* entirely absent, for ice-cream after production has been completed. This standard should be easily attained, as efficiently pasteurised milk, which does not possess the advantage of storage and distribution at temperatures below freezing-point, rarely exceeds these limits.

(5) Chemical Standard.—No chemical standards have been fixed in this country for ice-cream, and it is a fact that much of the so-called "ice-cream" does not contain any cream, and in some cases does not even contain any whole-milk.   Steps are apparently being taken to fix a legal standard of quality as the Minister of Food has recently asked manufacturers to make recommendations regarding this matter through their trade associations. It would appear necessary, also, that Local Authorities should be consulted, particularly when it is remembered that the onus of enforcing legal standards for food falls upon these bodies and their officials.   In the United States of America, various standards of butter-fat percentage have been fixed.   These vary from 6 to 14 per cent., while the total milk solids are fixed at 18 to 33 per cent.   In fixing a standard for butter-fat, the following points should be borne in mind :

(*a*) The solids other than fat possess a high nutritional value.
(*b*) Butter-fat in excess is expensive to provide, and increases the price of the product.
(*c*) High fat percentage renders the product too rich for young children to digest.
(*d*) Ice-cream has not been generally recognised as a food, and is eaten chiefly for its palatability and refreshing qualities.   A product with a reasonable fat content is more palatable and more refreshing than a rich ice-cream.

Suitable standards for the product as sold would be:

"Cream ices" should contain not less than 10 per cent. of butter-fat and 20 per cent. total milk solids.

"Ice-cream" should contain not less than 4 per cent. of butter-fat and 10 per cent. of total milk solids.

Substances containing less percentages of butter-fat and total solids than that specified for "Ice-cream" should be designated "Ices." The moisture content should not exceed 66 per cent.

It should be pointed out that these must be regarded as peace-time standards. Since the ban on the sale of ice-cream was lifted, vegetable oils have replaced butter-fat in its production, but large quantities of these materials are not available. It would, therefore, be most unfair for any chemical standard to be fixed at the present time, particularly when the prohibition of milk or milk products in manufacture is considered, but this step should be taken immediately conditions return to normal.

(6) Distribution.—Given a suitable article produced under hygienic conditions, the distribution of the said article should be strictly controlled. In the case of ice-cream, the following conditions are suggested:

(a) Cleanliness of all vehicles and receptacles to be scrupulously maintained and the product to be protected from contamination by dust, flies, and insects. Vehicles and containers to be cleansed immediately after use.

(b) Persons employed in distribution to keep clothing, hands, and person clean.

(c) When purveyed by a retailer from any premises or vehicle which is likely to become contaminated, the product to be sold in closed packets or cartons from a suitable refrigerator.

(d) No container or wrapper to be used which can contaminate or impart any odour to the product. Old containers not to be refilled. Such containers or wrappers to be of first-grade quality.

(e) Metal containers used for bulk storage and distribution to be constructed of such materials as will not contaminate or taint the product.

These conditions, if vigorously enforced, would result in a standard product, hygienically produced. Such an article would not only possess appreciable nutritional value, but would also enjoy the inestimable advantage of being guaranteed *safe* for human consumption.

CHAPTER II

CREAM

Introductory

CREAM is one of the most important products of milk, partly because of the ready sale which it enjoys in its natural state, and partly because it is the prime constituent of butter and of certain varieties of cheese. It possesses a considerable food value, and is particularly valuable during sickness and convalescence, not only by virtue of the nourishment which it contains, but also because of its palatability. Cream furnishes the body with heat and energy and contains most of the colouring matter, known as carotene, found in milk.

Cream represents milk in which the normal proportion of fat has been increased, mainly at the expense of the water removed during the process of separation or skimming. The quantity of protein and sugar present in cream is approximately half that contained in average cow's milk, although the fat percentage may vary considerably according to the method of separation.

Prior to the war, cream in one form or another had become an article of everyday diet. Particularly was this so in London and the surrounding districts, where various types of cream, such as "Utility Cream," "Coffee Cream," and "Half-price Cream," were sold in large and increasing quantities for a variety of purposes. There can be little doubt that such types of cream, sold at reduced prices, were sufficiently low in cost to render their daily use economical and to place them within the reach of the majority of consumers. The distribution of liquid cream had reached considerable dimensions when war-time restriction dictated total prohibition.

Definition and Varieties of Cream

Cream may be defined as that portion of milk which is rich in butter-fat and which has been separated by skimming or by other means, usually a mechanical separator. In the United States of America, the following official definition is applied:

"Cream is that portion of the milk, rich in milk-fat, which rises to the surface of milk on standing, or is separated from it by centrifugal force. It contains not less than 18 per cent. of milk-fat and not more than 0·2 per cent. of acid-reacting substances, calculated in terms of lactic acid."

A legal standard of butter-fat percentage has not been fixed for this substance in Great Britain, although standards have been legalised in the United States of America, as follows:

Fresh Cream . . .	18 per cent. butter-fat
Double Cream . . .	36 per cent. butter-fat

The Sanitary Code of the City of New York (1943) prescribes the following chemical standards for cream:

Light Cream . . .	At least 18 per cent. butter-fat
Medium Cream . . .	At least 25 per cent. butter-fat
Heavy Cream . . .	At least 36 per cent. butter-fat

In addition, cream when delivered to the consumer must be pasteurised and must not contain more than 100,000 bacteria per millilitre.

As previously stated, various types of cream possessing a multitude of uses have been and will again be retailed in this country, and for these the Standing Committee of the Council of Agriculture for England some years ago suggested the following standards:

Coffee or Breakfast Cream	.	12 per cent. butter-fat
Fruit Cream	. . .	25 per cent. butter-fat
Whipping Cream .	. .	50 per cent. butter-fat

The percentage of butter-fat in mechanically-separated cream is considerably higher than that in cream removed from milk by skimming. The reasons governing this will be specified later. "Utility Cream," which has a similar butter-fat content to "Coffee Cream," usually contains from 12 to 18 per cent. of butter-fat, while thick cream may contain any quantity up to 65 per cent. of butter-fat, according to the degree of separation to which the milk has been subjected. Prior to the war, the sales of light creams had reached such proportions that it is doubtful if the market for heavy cream will ever be re-established when restrictions are lifted. Clotted or scalded cream usually contains from 60 to 70 per cent. of butter-fat, whereas tinned cream, which is imported in large quantities, is a less valuable article, generally containing not more than 20 to 30 per cent. of this substance.

Properties and Composition of Cream

The specific gravity of cream varies from 0·947 to 1·017, averaging 0·985. The average weight of one gallon of cream is 9·85 lb. Cream consists of the fat globules present in the original milk, together with a certain quantity of milk protein which adheres to these particles after separation. This occurs more particularly in hand-skimmed cream. It is the lactic acid in milk which tends to precipitate the casein in a gelatinous form around the fat globules. Because of this, a slightly acid milk produces a thick cream. Fresh milk yields a thin cream, owing to the fact that the protein is in finer suspension, but if such cream is allowed to stand for some time, the lactic acid content increases and the cream thickens accordingly.

Table 6 sets out a number of average analyses of various types of cream.

TABLE 6

	Per cent. Fat	Per cent. Protein	Per cent. Lactose	Per cent. Ash	Per cent. Water
Coffee Cream . .	15·20	3·10	4·50	0·60	76·60
Fruit Cream . .	24·44	4·04	2·96	0·63	67·93
Medium Cream . .	36·20	6·00	2·50	0·30	55·00
Thick Cream . .	58·77	1·83	1·46	0·32	37·62
Clotted Cream . .	67·50	4·90	1·00	0·50	26·10

The quantity of cream which may be obtained from a given sample of milk depends upon the quality and composition of such milk. This, in turn, is governed by certain factors, as follows:

(1) Breed of cow.
(2) Individuality of cow.
(3) Seasonal variations.
(4) Efficiency of milker.

(5) Period of lactation.
(6) Feeding.

(1) **Breed of Cow.**—If milk containing a high percentage of fat is required, the breed of cow is important. Heavy-yielding animals generally produce milk which has a low fat content, while the milk of poor-yielding animals usually possesses a high fat percentage. This matter is governed and equalised by a process of selective breeding. The various pure breeds of cattle usually kept for milking purposes in this country are set out below, in the order of their position as regards the butter-fat content of their product.

(a) Jersey and Guernsey.
(b) Kerry and Dexter Kerry.
(c) Welsh Black.
(d) South Devon.
(e) Ayrshire.
(f) Red Poll.
(g) Shorthorn.
(h) Lincoln Red.
(i) Friesian.

It will be observed that the highest percentage of butter-fat is contained in the milk of the Jersey and Guernsey breeds. The milk of these breeds also possesses the advantage that the fat globules contained are larger than those present in the milk of other breeds. Consequently, the cream is more readily separated from such milk.

(2) **Individuality of the Cow.**—Individual cows of similar breeds often show great variations in the butter-fat content of their milk, variations up to 1 per cent. having been observed. This phenomenon occurs apart from age, breed, or period of lactation.

(3) **Seasonal Variations.**—Owing to a variety of circumstances, the composition of milk varies with the seasons. Winter milk is usually richest in fat, summer milk being greatest in quantity.

(4) **Efficiency of Milker.**—The butter-fat percentage of the milk may be reduced by an inefficient milker failing to strip the udder properly. Stripping is exceedingly important, as the last-drawn milk may contain as much as 9 per cent. of butter-fat.

(5) **Period of Lactation.**—The effect of the period of lactation upon the butter-fat percentage of milk is important. The percentage of fat in milk is lowest at the time of the animal's highest yield, while, with average animals, the percentage of butter-fat increases as the quantity declines.

(6) **Feeding.**—Feeding may affect the percentage of butter-fat in milk for a short period, but this is a factor of minor importance.

Cream usually possesses a high cellular content, which is due to the manipulation of the udder during the stripping process.

Bacteria in Cream

The bacteria which may be present in cream can be separated into two groups:

(1) Pathogenic.
(2) Non-pathogenic.

(1) **Pathogenic Bacteria.**—The pathogenic organisms met with in cream are similar to those found upon occasion in milk. Such organisms are capable of producing disease in the human subject. They may in turn be divided into two classes:

(a) *Organisms of Animal Diseases.*—These obtain entrance to the cream following a diseased condition in the animal. The principal organisms of this group likely to be found in cream are as follows:

(i) *Mycobacterium tuberculosis.*
(ii) *Brucella abortus.*
(iii) Streptococci of various types.

(b) *Organisms of Human Diseases.*—The causative organisms of the following diseases may be present in cream as a result of infection from human sources:

(i) Typhoid fever.
(ii) Paratyphoid fever.
(iii) Dysentery.
(iv) Diphtheria.
(v) Scarlet fever.
(vi) Septic throat.

The sources of the pathogenic bacteria found in cream are similar to those of the same organisms met with in milk, and may be summarised as follows:

(i) The animal itself—udder, sore teats, coat, fæces, or urine.
(ii) Persons handling the cream.
(iii) Fly infection.
(iv) Air of the cowshed and dairy.

(2) **Non-pathogenic Bacteria.**—Fortunately for the consumer, the non-pathogenic bacteria found in cream considerably outnumber the pathogenic group. The principal organisms of this type are lactic-acid-producing bacteria and organisms of the coli-aerogenes group. The lactic-acid organisms make up by far the larger proportion of the bacteria present in the product.

The sources of the non-pathogenic organisms found in cream are as follows:

(a) The animal.
(b) The air of the cowshed and dairy.
(c) Dirty utensils used in production.
(d) Careless handling.
(e) Dirty containers used for delivery.
(f) Fly contamination.

Diseases transmitted by Cream

Instances of animal diseases transmitted by cream are rare, but the possibility is ever present if cream is not pasteurised before sale. Several outbreaks have occurred due to the contamination of cream by organisms of human disease. Particulars of three such outbreaks are appended.

A typhoid fever outbreak occurred in Liverpool in 1896, in which twenty cases were notified. Sixteen of the cases, occurring in nine houses, had consumed milk or cream from a particular dairy. It was later discovered that certain of the milk-cans belonging to the dairy had been left tempo-

rarily at a house from which a case of typhoid fever had been notified. It would appear that the cans were infected on these premises, the cream and milk being subsequently infected at the dairy.

An outbreak of paratyphoid B. fever involving eighty-seven cases was reported from Leamington in 1924. Sixty per cent. of the cases had consumed confectionery obtained from an establishment where a "carrier" was found. The medium of infection was presumed to be the cream used for filling in cream cakes.

In July and August 1928, 400 cases of paratyphoid B. fever were notified in western Metropolitan Boroughs and in districts in Surrey, Middlesex, Hertfordshire, and Kent. Cream obtained from one wholesale dealer was implicated. This dealer obtained his supply from three sources, two of which were situated abroad. It was established that the cream had not been infected at the wholesaler's premises, but the actual point at which infection had occurred was not traced. The cream was "commercially" heat-treated by the wholesaler, a very doubtful advantage, and it is probable that such treatment was either inefficient or that a certain proportion of the cream had not been sufficiently heated.

Separation Methods

The butter-fat in milk is present in the form of small globules, which vary in size according to the breed of animal producing the milk, although they may also be affected by the period of lactation. These globules resemble minute droplets of oil, and conform to the physical law which determines that, if a mixture of oil and water is allowed to stand, the oil will quickly rise to the surface. In a similar manner, the butter-fat of milk, i.e. the lightest portion of the whole, will rise to the surface if the product is allowed to stand. It can then be skimmed or poured off, leaving behind the watery serum containing the protein and mineral salts.

There are three principal methods of separating cream from milk, two of which rely upon hand skimming, which is still carried out in many farmhouse dairies. The earliest method was to strain the warm milk, immediately after it left the cowshed, into shallow setting pans, 12 to 24 inches in diameter and having a depth of 2 to 4 inches, each pan holding approximately 1 gallon of milk. The pans, when filled, were allowed to stand in a cool dairy for twenty-four to thirty-six hours (temperature approximately 55° F.). The cream was removed from the surface of the milk by means of a shallow skimmer. This process possesses several obvious disadvantages. The removal of the cream in this manner is never complete, the skimmed milk retaining from 0·5 to 1·0 per cent. of the butter-fat, while the cream produced is dependent upon the time the milk is allowed to stand, the temperature, the type of milk-fat and the depth of skimming. A further disadvantage is the fact that the casein contained in the milk frequently curdles before the cream has finished rising, thus preventing complete creaming of the milk.

To overcome these difficulties, the "deep setting" system was devised. Where this method is used, the milk is placed in cans some 8 to 10 inches in diameter, each can being approximately 20 inches in depth. The cans are so constructed that their contents may be cooled by means of water or iced water, in order to prevent the souring or curdling of the milk. The method of removing the cream varies according to the individual ideas of the person in charge. After the milk has been kept standing for the requisite period,

the cream may be removed by hand with a shallow skimmer, or the cans may be arranged in such a way that the skimmed milk can be drawn from the bottom without disturbing the cream. This method yields a better-quality cream than that obtained from setting in shallow pans, while, if carefully operated, not more than 0·2 per cent. of butter-fat will be left behind in the skimmed milk. Hand skimming removes between 25 to 30 per cent. of the milk fat. Hand-skimmed cream usually possesses a higher bacterial content than that mechanically separated from milk, as the bacteria present in the milk tend to rise with the cream during the setting process.

When the cream is desired in reasonably large quantities, it is necessary to replace the methods previously described by the use of a *mechanical separator*, either hand- or power-driven. The first continuous-flow cream separator was introduced by Neilson, a Danish inventor in 1878. The first separators were of the hollow-bowl type and possessed siphons to carry away both the cream and the separated milk. The bowls were large compared to present-day apparatus, and required considerable power to drive them ; but this fault was later remedied by reducing the bowl diameter from 20 to 10 inches. Discs were later introduced, providing both increased capacity and skimming efficiency. Separator bowls were formerly fixed on their driving spindles, but a self-balancing bowl which is placed loosely on the spindle -head and automatically finds its own centre of gravity as the machine gathers speed was later introduced.

The mechanical separation of cream from milk depends upon the difference which exists between the specific gravity of the milk serum (1·036) and that of butter-fat (0·9). When mechanical separators are used, perfectly fresh milk can be separated, there being no necessity for the milk to stand prior to separation. Mechanical separation possesses many advantages over the old method of "setting" milk, chief among which are:

(1) A greater percentage of butter-fat is removed from the milk, practically the entire amount being obtained.

(2) The richness of the cream can be regulated and various types of cream thereby produced.

(3) Considerable saving of labour and space in the dairy is effected.

(4) The cream is perfectly fresh, while the bacterial content is accordingly low.

(5) The separated cream possesses a low lactic-acid content.

Mechanical Separation

Three standard types of mechanical separators are used. These are:

(1) DISC PLATE TYPE.—This is the type in most general use (see illustration on page 89). The machine is built up with a series of cones or discs which fit into a revolving bowl. The milk is fed in at the upper end of the machine, the cream being discharged from one opening while the skimmed milk leaves by another.

(2) CURVED PLATE TYPE.—This machine is very similar to Type 1, but instead of discs it possesses a series of curved plates directing the course of the milk in its passage through the milk bowl.

(3) TUBULAR BOWL TYPE.—This apparatus possesses a long tubular bowl and operates at an exceedingly high speed. The milk passes into the separator at the base and, as it rises up the bowl, the cream is separated by means of centrifugal action. The completeness of the separation, together with the quantity of cream and skimmed milk obtained, depend upon the speed of the bowl, the uniformity of the speed, and the temperature of the milk and rate of inflow. The physical and chemical condition of the milk itself also exerts an influence upon the completeness of the separation.

Separators may be hand-operated, may obtain their power from an electric motor, or be steam-turbine driven. Hand-operated separators are usually employed for small-scale production on farms where cream is required for butter-making or for immediate use. The speeds obtained by hand operation are neither so high nor so constant as those of the electrically driven apparatus, varying according to the capabilities of the operator. For this reason, the higher initial cost of the power-driven type is finally an economy, as a better cream is obtained when a constant speed is maintained, while the percentage of fat remaining in the skimmed milk is greatly reduced. This latter should never exceed 0·01 per cent, and if in excess of this figure, the apparatus may not be separating at a high enough temperature, or some mechanical defect may have developed.
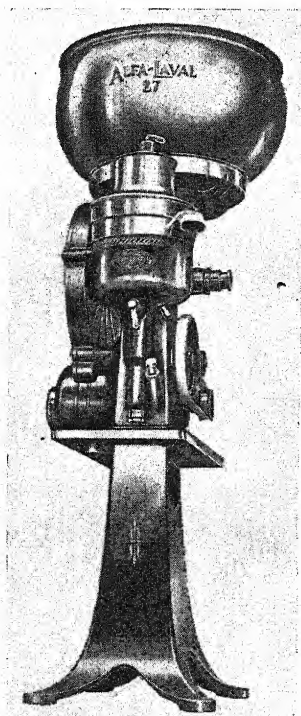
By courtesy of Alfa-Laval, Ltd.

FIG. 25—Modern Cream
Separator
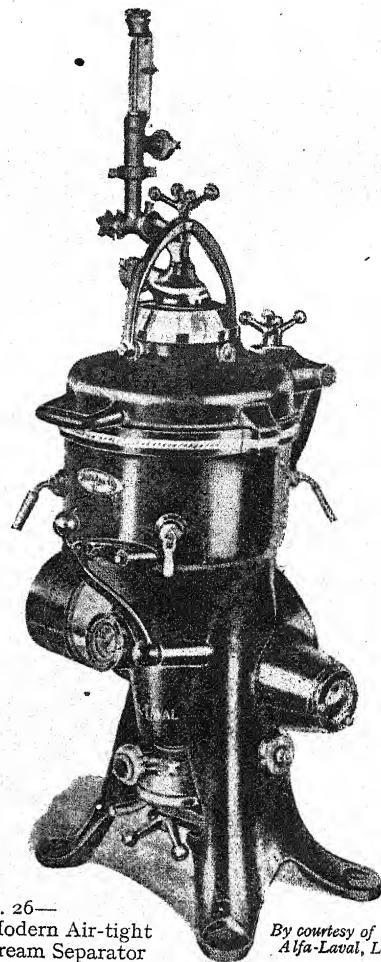
FIG. 26—
Modern Air-tight
Cream Separator

By courtesy of
Alfa-Laval, Ltd.

Air-tight separators of the type illustrated in Fig. 26 have been designed for use in creameries and they are constructed so that no air can enter the bowl or come into contact with the milk during separation. The milk is fed to the bowl from the base of the apparatus by means of a hollow spindle and this milk-line is air-tight as is the bowl itself. A constant pressure is maintained which forces the cream and skimmed milk through the separator without the admixture of air or the formation of foam, while a higher skimming efficiency is attained.

Special separators have also been devised which will produce a cream containing over 80 per cent. butter-fat. This is termed "plastic cream," and on leaving the separator it is cooled by passing over a chilled roller.

The various types of separators are generally provided with means of adjustment, the passage of the milk through the apparatus being regulated in such a way that the operator retains perfect control of the separation. The higher the speed at which the machine operates, the more completely is the cream separated. As an instance of this, the figures given by Walworth may be quoted. If the separator revolves at fifty revolutions of the crank per minute, the cream produced will contain 21·3 per cent. of fat, while 0·034 per cent. of fat will be retained in the skimmed milk. If, however, sixty revolutions of the crank per minute are maintained, the cream produced will contain 30·9 per cent. of fat, leaving only 0·024 per cent. of fat in the skimmed milk. By suitable adjustment of the machine, any type of cream may be obtained. Thus, retailers of fruit cream or utility cream, sold at reduced prices, take advantage of the adjustments provided on an up-to-date separator, in order to produce an article containing varying percentages of fat. Ten gallons of milk will yield approximately 7 pints of cream with a 50 per cent. butter-fat content, or 1 gallon of whipping cream of 35 to 38 per cent. fat content, or approximately 2 gallons of thin cream with a fat content of 22 to 25 per cent.

The temperature of the milk prior to separation is important. The ideal temperature at which separation should be carried out is approximately 90° F. The milk should preferably be cold prior to the commencement of separation and should be warmed quickly just before this process takes place. At higher temperatures, the viscosity of the milk may be reduced, giving a poorer cream, although loss of fat in the skimmed milk is diminished. Lower temperatures, on the other hand, increase the viscosity, with a correspondingly richer cream and a consequent greater loss of fat in the skimmed milk. Guthrie gives the following figures relating to the separation of milk of different temperatures:

TABLE 7

Temperature	Per cent. of fat in cream	Per cent. of fat in skimmed milk
75° F.	43·12	0·069
80° F.	36·75	0·039
90° F.	29·83	0·020

It is also important that the cream should be cooled after separation, flowing over a cooler on the way to the pasteuriser, or cooled, without excessive agitation, while it is in that apparatus.

The completeness of separation, which in turn governs the thickness of the cream, is affected by the rate at which the milk flows into that portion of the machine which completes the separation process. The rate of inflow in modern machines is regulated by an adjustable float system which ensures that the separated cream will possess an even composition.

The percentage of butter-fat in the separated milk exercises an effect upon the cream produced. The more butter-fat contained in the milk, the richer will be the cream obtained by separation. It may be generally

stated that the percentage of fat in the cream is proportionate to that in the whole milk prior to separation. Guthrie reports the results of experiments as follows:

(1) Three per cent. milk gave a cream containing 23·8 per cent. of fat.
(2) Four per cent. of milk gave a cream containing 31·2 per cent. of fat.
(3) Five per cent. milk gave a cream containing 43·4 per cent. of fat.

The same separator was used in each case.

Modern mechanical separators make use of centrifugal action for separation purposes. The liquid is spun on a disc which impels the heavier portions of the milk, i.e. the watery serum, towards the circumference, while the lighter portion, i.e. the fat, is left nearer the centre. Fig. 27 illustrates the method of operation of the disc separator. The incoming milk displaces the skimmed milk and fat, and is itself separated in turn. As will be seen from the illustration, the skimmed milk is drawn from the outer side of the separator, while the cream is drawn from the inner layer.

A separator of this type would operate in the manner illustrated, but, in practice, the time taken in separation would be too great, owing to the distance which the fat globules would require to travel through the milk serum. The addition of a number of plates, as shown in Figs. 28 and 29, will increase the speed of separation, modern machines being commonly fitted with a considerable number of such appliances.
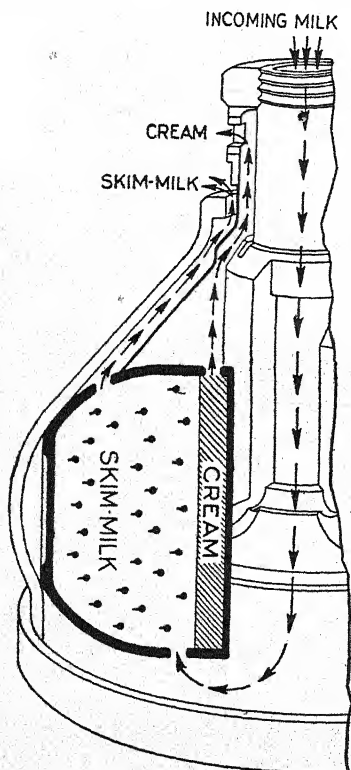
By courtesy of Alfa-Laval, Ltd.

FIG. 27—Sketch illustrating Action of Separator without Discs
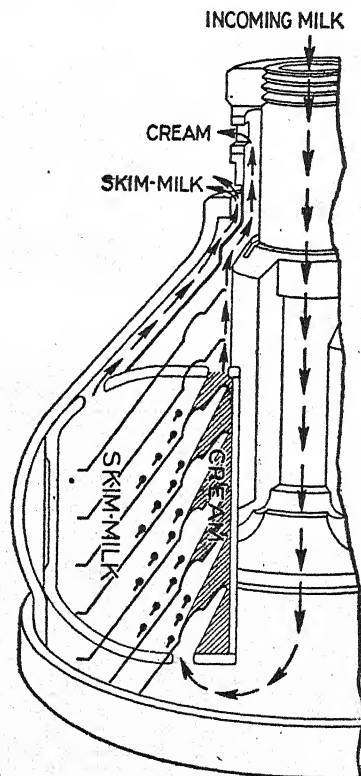
By courtesy of Alfa-Laval, Ltd.

FIG. 28—Sketch illustrating Improved Separation by addition of Discs to Separator

The action of the machines illustrated in Figs. 27 and 28 is identical, but the increased number of plates reduces the distance which the fat globules have to travel, and so speeds up the separation process. Fig. 29 illustrates a modern mechanical separator, in which the whole milk is delivered through the centre of the bowl on to a series of plates. The rapid revolution of the bowl throws the skimmed or watery portion of the milk towards the outside of the plates, the cream remaining near the axle. The plates are slanted to assist in completing the separation.

The actual *installation* of any separator is of the greatest importance. It should be remembered that machines relying upon centrifugal action continually revolve at high speeds, so that, if absolute efficiency is to be maintained, the supporting axle must be absolutely vertical. The slightest deviation will result in an uneven drag upon the bearings, which will quickly cause trouble with the machine. It is therefore essential that the plant should be absolutely level when installed, and that it should be fixed rigidly to a firm base.
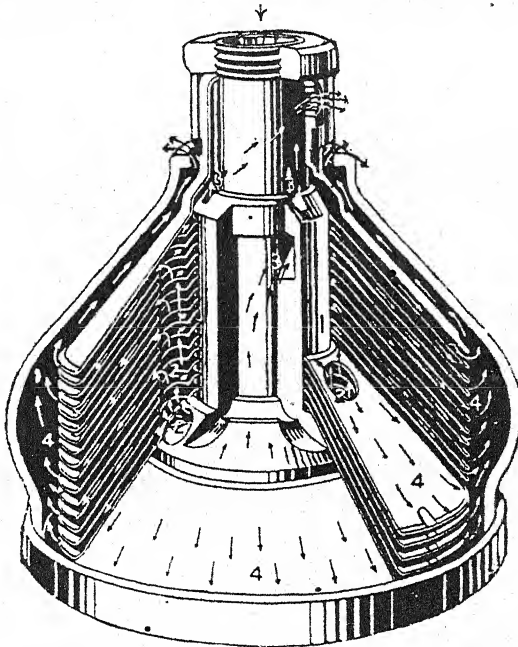
By courtesy of Alfa-Laval, Ltd.

FIG. 29—Cross-section of Alfa-Laval Separator Bowl

One other point requires attention. As with all other appliances which come into contact with food for human consumption, cleanliness is of especial importance. Modern machines are simple to dismantle, and, after separation operations have been completed, they should be dismantled and the parts washed thoroughly in hot water (180° F.), following which they should be sterilised by steam or sodium hypochlorite solution before being reassembled. By paying strict attention to cleanliness, a raw cream possessing a low bacterial content can and should be produced. Special care is necessary in replacing the discs after sterilisation is completed. Each disc usually bears a number stamped on the metal and it is essential that the discs should be arranged in their proper order so that a proper balance is maintained.

Pasteurisation

In view of the fact that cream, in common with milk, may be a potent source of human infection, it is essential that all cream should be efficiently pasteurised before being sold for human consumption. This procedure is advisable, not only from a public health point of view, but also from a commercial standpoint. Indeed, when it is remembered that the addition of preservatives to cream is prohibited, treatment of cream by the pasteurisation process becomes an inevitable corollary to the improvement of its keeping qualities.
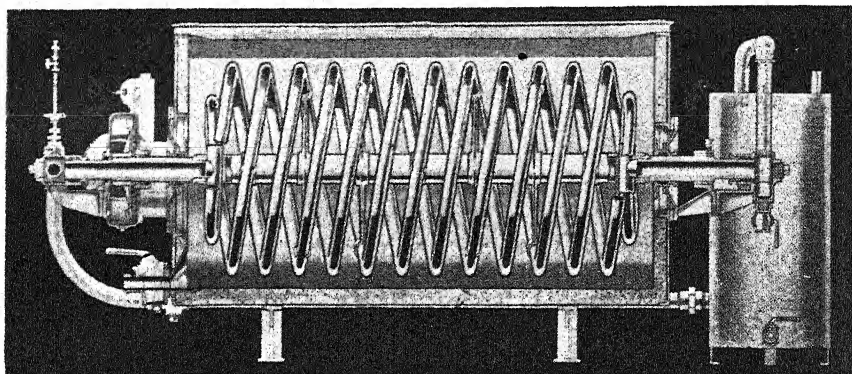
By courtesy of Cherry-Burrell, Ltd.

FIG. 30—Coil-type Cream Pasteuriser (Section)

Efficient pasteurisation is essential if the cream is to be rendered *safe*, if its keeping quality is to be improved, and if its food value is to remain unimpaired. For those reasons, the cream should be held for thirty minutes between temperature limits of 145° and 150° F. or for 15 seconds at 162° F. or over. Temperatures considerably higher than these are often used, such temperatures being applied for shorter periods, but, while this procedure is not illegal, it cannot be considered satisfactory. Pasteurisation will injure the viscosity of the cream and, although homogenisation will normalise this, milk is sometimes pasteurised before separation takes place.

Cream is generally heated and held for the requisite period in a pasteuriser of a type similar to that illustrated in Fig. 30. This holder is eminently suited to its purpose, as it is not over-large, thus ensuring quick heating of the cream and economy of operation. The plant illustrated, which possesses an internal surface of stainless steel, has been specially developed for processing cream in order to overcome the difficulties which have always accompanied the heating and cooling of this highly viscous product. In this apparatus, the cream is heated, held, and rapidly cooled in one vessel. The heating and water cooling are carried out by means of the coils, while the final brine cooling reduces the temperature to 45° F. Rapid cooling is essential if bacterial growth is to be retarded, and the innovation of heating and cooling in one apparatus prevents any possibility of the cream becoming contaminated during cooling operations.

The large agitator coil provided ensures complete agitation and produces rapid heating and cooling. It is essential that the heating medium should not be too hot and that the cream be warmed quickly to the necessary

temperature, while the pasteuriser should be almost full during processing if satisfactory results are to be obtained.

The Cherry-Burrell Cream Pasteuriser (Fig. 31) has been specially designed for the purpose. It possesses an internal stainless-steel surface and the cream is heated and cooled in the one vessel. A large agitator paddle is provided which ensures both rapid heating and cooling and, if desired, the apparatus can be provided with a bottle filling and capping attachment as shown.

A process for the pasteurisation of cream has been patented in the United States of America in which the substance is processed under vacuum at temperatures in the region of 200° to 250° F. or higher. The flavour of the cream is said to be greatly improved, while the substance is practically sterile. Heat-treatment is extremely brief, as the cream travels at a speed of 3 to 5 lb. per second past a given point under a pressure of 10 lb. per square inch or over. It is then explosively expanded in a heated vacuum chamber and finally cooled.

After pasteurisation, the cream must be cooled. To be satisfactory, cooling should reduce the temperature to 45° F., refrigeration being used for this purpose. This is essential if bacterial growth is to be retarded. A coil-type

By courtesy of Cherry-Burrell, Ltd.

FIG. 31—Cherry-Burrell Cream Pasteuriser

cooler is often employed for this purpose. This consists of a horizontal tank in which a revolving coil is fixed through which brine is passed, the apparatus being similar to the pasteuriser illustrated in Fig. 30. Ordinary tubular surface coolers are also employed as are plate heat-exchangers if large quantities are to be handled. Care should be taken to prevent the possibility of any re-contamination of the cream during cooling operations, otherwise the keeping quality may be reduced by as much as 50 per cent. It is important to ensure that the cream is agitated as little as possible during cooling. Cream is sometimes aged for eighteen to twenty-four hours at refrigeration temperature. Longer ageing is never justified as, if carried to excess, the keeping quality is reduced and the whipping properties are not improved.

High-temperature pasteurisation is sometimes employed by means of a short-time plant of the plate-type heat-exchanger illustrated in Fig. 32. With this apparatus, efficient cooling, free from the possibility of re-contamination, is also obtainable.

It is essential that all the apparatus employed should be dismantled after use, cleansed thoroughly, and efficiently sterilised before again being put into operation. Only by the exercise of strict cleanliness can the output of a suitable pasteurised product be maintained.

FIG. 32—Plate type Cream Pasteuriser

Homogenisation

Cream is often homogenised to increase its viscosity, the higher the pressure to which it is subjected during the process, the greater being the increase in this direction. Such increase in viscosity enhances the flavour, appearance, and palatability of the cream, the resultant product being completely homogeneous in character, due to the rupture of the fat globules
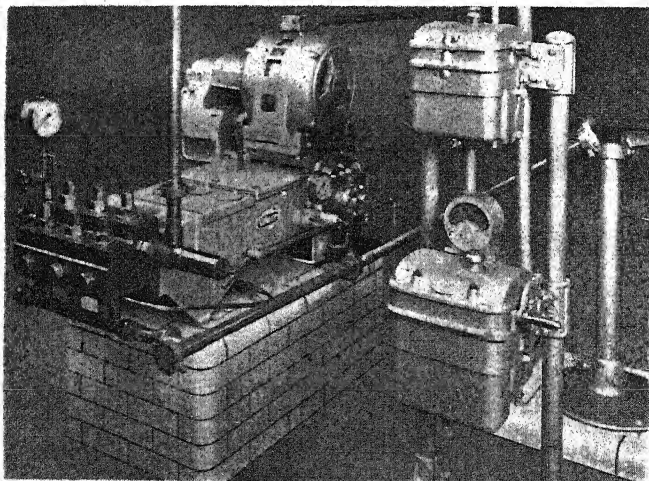
FIG. 33—Homogeniser for Cream

and the distribution of these minute particles throughout the mixture. No change takes place in the chemical composition during the process, but serum separation is prevented. High-fat cream is not usually homo-

genised, this process being generally confined to creams possessing 18 to 35 per cent. butter-fat content. Homogenisation of cream is essential if the product is to be canned.

Commercially, cream is usually homogenised at a pressure of approximately 1,700 lb. per square inch, the process taking place after pasteurisation at a temperature of 130° F., and before cooling. Double-stage homogenisation is sometimes employed. The first stage is carried out at a pressure of 1,500 lb. per square inch, with pressures of 800 to 1,000 lb. per square inch for the second stage. The second stage treatment prevents the clumping of the fat globules. It should be noted, however, that the pressures used in this process vary greatly according to the fat content of the cream. Pressures as low as 300 to 400 lb. per square inch have been successfully used with cream possessing a high fat content. The homogeniser illustrated in Fig. 33 is quite suitable for this purpose. The apertures through which the liquid is forced are exceedingly minute, the fat globules being broken up during their passage from a region of high pressure into a low-pressure atmosphere, plus the action of the valve facings.

The homogeniser must be efficiently cleansed and sterilised after use.

Viscosity of Cream

The average consumer judges the quality and fat content of cream by its viscosity, and, if sales are to be increased and maintained, it is essential that this point should receive attention.

Generally speaking, viscosity depends upon certain factors, these being:

(1) Size of fat globules.
(2) Butter-fat content.
(3) Pasteurising temperature.
(4) Age and temperature.
(5) Homogenisation.
(6) Cooling.

(1) **Size of Fat Globules.**—The viscosity of cream depends partly upon the tendency of the fat globules which it contains to coalesce. This agglutination depends in turn upon three factors:

(a) Temperature.
(b) Size of globules.
(c) Agitation.

It has been proved by experiment that maximum agglutination takes place at a temperature of 45° F., while, at temperatures above 140° F., little or no coalescence occurs. As might also be expected, the larger the fat globules, the more easily do they coalesce. Agitation of the product at low temperatures will cause agglutination, whereas, if cream is agitated at high temperatures, clumps which have already formed will be dispersed.

(2) **Butter-fat Content.**—This naturally affects viscosity, as the greater the fat content, the more fat globules will be present in the cream to form clumps.

(3) **Pasteurisation.**—The pasteurisation process tends to decrease viscosity. Certain investigators have reported that the higher the pasteurisation temperature, the lower will be the viscosity of the cream. Babcock reports, however, that the temperature of pasteurisation has little

effect on viscosity, 20 per cent. cream pasteurised at 176° F. possessing practically the same viscosity as that pasteurised at 144° F. At the same time, it would appear that the higher the percentage of butter-fat which the cream contains, the greater will be the influence which pasteurisation is likely to exert upon the viscosity. Babcock also reports that cream separated from milk which had been pasteurised before separation possessed a lower viscosity than that of similar cream first separated and then pasteurised. Hemming and Dahlberg report a method of increasing and controlling the viscosity of pasteurised cream. These workers have shown that, when cream at a temperature of 40° F. is warmed to 80° to 84° F. in an internal tubular heater for three to ten minutes, afterwards being cooled to 40° to 48° F. in an internal tubular cooler over the same period, a noticeable increase in viscosity can be obtained. They also report that 30 to 40 per cent. cream treated in this manner will yield even more marked results than can be obtained in the case of 20 per cent. cream.
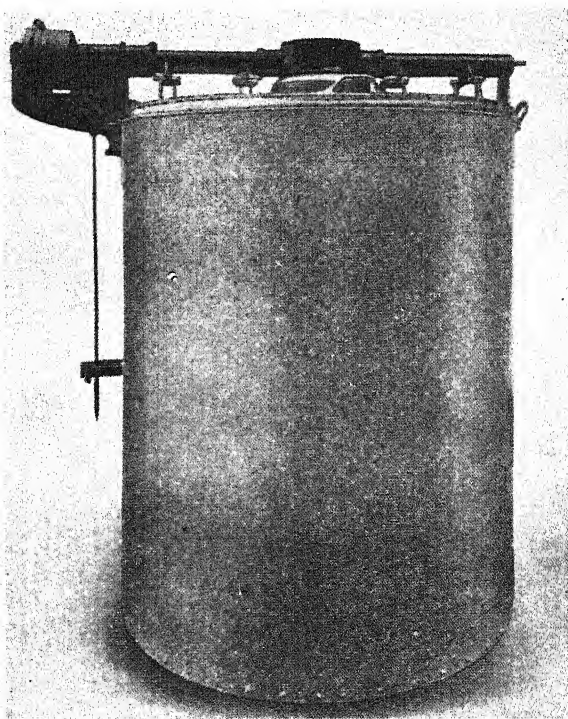
By courtesy of Cherry-Burrell, Ltd.

FIG. 34—Cream Storage Vat (Exterior)

(4) **Age and Temperature.**—The ageing of cream at low temperatures will increase its viscosity even before sufficient acidity develops to coagulate the casein, whether the product be raw or pasteurised, while cream will normally thicken at low temperatures. Babcock reports, however, that ageing has no effect upon pasteurised, homogenised cream. He also found that the greatest *increase* in viscosity took place during the first twenty-four hours of ageing, the maximum being approached after an ageing period of forty-eight hours.

(5) **Homogenisation.**—As previously indicated, homogenisation will increase the viscosity of cream, the higher the homogenisation pressure, the greater being the increase in viscosity. Homogenised cream has a tendency to "feather" in coffee, and for this reason high homogenising pressures are seldom employed.

(6) **Cooling.**—Experiments conducted by Babcock appear to show that the rate of cooling of cream exerts a decided effect upon viscosity. Slow cooling of either raw or pasteurised cream considerably increases the viscosity over that of the same cream when cooled rapidly.
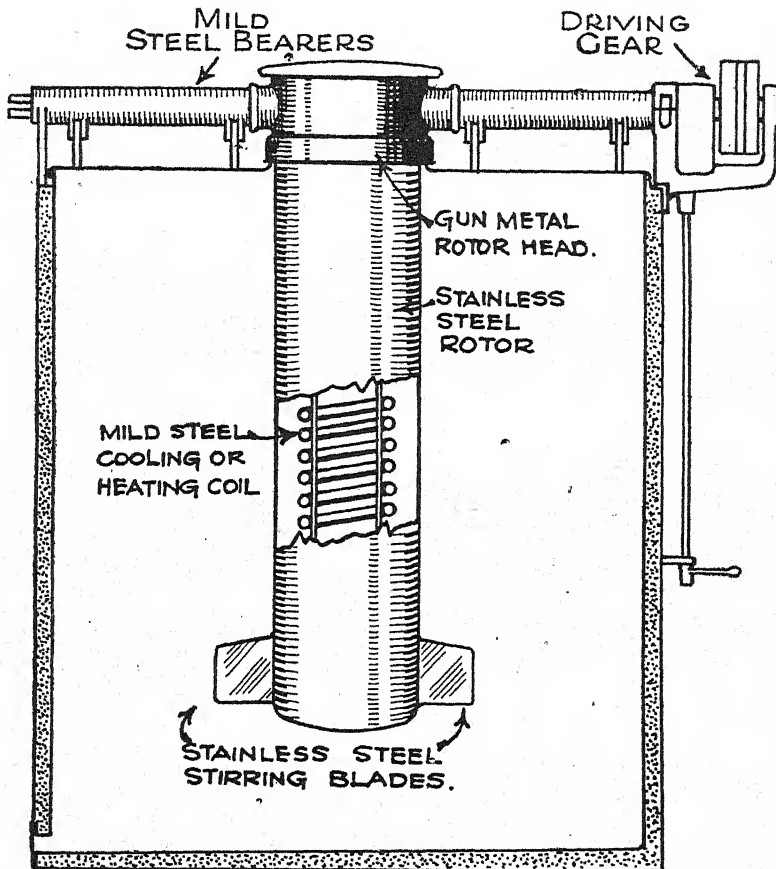
By courtesy of Cherry-Burrell, Ltd.

FIG. 35—Cream Storage Vat (Section)

Storage and Sale of Cream

It has been proved, following investigation, that high-quality cream can be kept in storage at 0° F. for periods up to six months without its quality and flavour becoming impaired. The cream must be perfectly fresh when stored, and clean containers must be used for storage purposes. It is essential that cream which is to be stored should not come into contact with any copper or iron surfaces as this will cause a metallic flavour which becomes more pronounced as the cream is aged.

The sale of cream deserves special, if brief, mention, as the methods in general use leave much to be desired. The usual practice is to deliver the product in waxed cartons, or, if sold from a shop, to fill the cartons as demanded from a basin of cream, often uncovered, which stands upon the shop counter. Such a practice may lead to serious contamination of the product. This is particularly the case with pasteurised cream, which, owing to its reduced bacterial content, is especially liable to recontamination if not carefully handled. The sale of cream which has not been efficiently pasteurised before sale should be made illegal, and further, permission should only be granted to retail the article in containers sealed at the dairy. It should always be remembered that efficient pasteurisation will improve the keeping qualities of the cream to a much greater extent than will the addition of any preservatives. The waxed cartons used do not exert any effect upon the flavour of the cream but it is important to ensure that no contamination takes place during storage and before they are filled. They should not be exposed to dust and should be unwrapped only in quantities as required for immediate use.

Defects in Cream

Cream, in common with other foodstuffs, may be subject to certain defects or faults due to unsatisfactory processing or handling. The purchaser requires a clean-flavoured product which possesses good keeping qualities, has a natural colour and sufficient viscosity to appear reasonably rich. If the cream is to be whipped, it should whip easily and produce a finished article of suitable stability. The principal defects found are:

(1) **Poor Keeping Quality.**—This is extremely important, particularly if cream is to be stored, unrefrigerated, in the home for any length of time. Extended ageing of cream will injure its keeping quality, while other factors which affect this property are high bacterial content of the milk from which the cream is produced, and the use of improperly sterilised utensils, apparatus, and containers.

(2) **Poor Flavour.**—Obviously, flavour depends upon the quality of the initial milk supply, and a clean, wholesome flavour is possible only when fresh milk of good quality is separated. Proper processing is essential so that the flavour is not injured, and cream should always be retailed in fresh condition. Ageing for lengthy periods in order to increase viscosity, should be avoided. Bitter or rancid flavours may develop due to non-spore-forming bacteria of soil and water origin, causing spoilage at low temperatures. These obtain entrance to the milk supply from bedding, utensils, or water. Mould growth may also occur and cause deterioration of flavour. Tallowy flavours are due to the oxidation of the fat content by exposure to strong sunlight or on account of contamination by contact with unsuitable metal surfaces during processing. Rancid or bitter taints may arise due to the action of lipase, the fat-splitting enzyme. This enzyme may be secreted in the milk of a few cows only, but if mixed with the bulk supply, will taint the whole quantity.

(3) **Cream Plug Formation.**—This is caused by excessive agitation of the cream in partially-filled tanks or cans, or by high-speed pumps. Cream should be cooled quickly and excessive heating must always be avoided.

(4) **Poor Colour.**—This depends upon the solids-not-fat content and the size of the fat globules. Partially-churned cream does not possess the colour of cream with the natural emulsion. Homogenisation will increase the colour as will building up the solids-not-fat content, but this latter practice may affect the flavour.

(5) **"Thin" Body.**—Too much handling, pumping, or agitation, separation at a high temperature or separating warm milk, and ultra-rapid cooling are the causes of this defect. It is important that the natural clumping of the fat globules should be encouraged by the proper handling of the milk before separation, gentle handling of cream, and slow cooling below 55° F.

(6) **Serum Separation.**—The factors responsible for this defect are excessive pumping causing partial churning of the cream, high-temperature separation, and low fat content. This defect, which is evidenced by fat rising and serum separation, does not occur if the viscosity is sufficient to retain the fat globules in position throughout the serum. Serum separation may be prevented by a high pasteurisation temperature, a low separation temperature and gentle agitation.

(7) **"Oiling Off."**—Causative factors are the freezing of the cream during cooling, separating excessively hot or cold milk, pasteurisation of very rich cream and the employment of very high temperatures, excessive agitation of warm cream prior to pasteurisation, high-speed pumping by centrifugal pumps, slow cooling in pasteuriser and using an excessively hot heating medium. Homogenisation at a pressure of 300 lb. per square inch will prevent this defect.

(8) **Feathery Cream.**—This type of cream is highly acid, possesses calcium or magnesium salts in excess, an abnormal mineral content or has been homogenised at excessive pressures, and will feather when added to coffee.

(9) **Poor Whipping Qualities.**—This is a defect sometimes found in whipping cream and is due to temperature and the type of whipping apparatus employed. Excessive ageing will cause this defect as will partial freezing and homogenisation. Sugar, which is sometimes added, should be mixed with the cream towards the end of this process. If added too early, the whipping ability will be lowered.

Bacteriological Examination

The technique governing the bacteriological examination of cream samples, including dilution of samples, plating, estimation of total bacterial content, and examination for the presence of *Bacillus coli* and other pathogenic organisms, is in many respects similar to that carried out in the case of ice-cream, as set out on pages 53 to 56, with certain modifications as regards sampling. It is usual to examine samples of cream for total bacterial count and for *Bacillus coli* content. The detection of certain pathogenic organisms, principally *Mycobacterium tuberculosis*, may also be necessary upon occasion.

Samples of cream are usually obtained at the dairy or at retail premises, generally direct from bulk containers. At least 10 mls. of cream should be obtained for each sample, and this should be transferred to a sterile, wide-mouthed glass bottle by means of a sterile dipper. The bulk cream should be thoroughly mixed by means of the dipper before any sample is

obtained. The bottles containing the samples should be packed in an insulated box, and preferably surrounded by ice, before being forwarded to the laboratory. Full particulars regarding each sample should be recorded upon the bottle or its container. In the case of cream sold in sealed bottles or cartons, one bottle or carton containing a suitable quantity should be obtained and forwarded to the laboratory unopened.

If cream is being purchased upon the basis of a bacterial count, it may be wiser to weigh the samples. In such cases, 10 grams of cream should be mixed with 90 mls. of sterile water and the subsequent dilutions prepared from the mixture.

The only satisfactory method of determining the presence of tubercle bacilli in cream is by means of *animal inoculation*. Fifty millilitres of the cream to be examined are divided into four equal parts. These are mixed with equal portions of distilled sterile water and centrifuged for thirty minutes at a speed of 3,000 revolutions per minute. The sediment from each of the four tubes is carefully decanted into a smaller, tapering centrifuge tube under sterile conditions, and is respun for fifteen minutes at a similar speed to that used upon the first occasion. The liquid is finally decanted and the sediment mixed with sufficient sterile saline to make an emulsion of three millilitres capacity. This emulsion is drawn into a sterilised hypodermic syringe for inoculation into a guinea-pig.

Two guinea-pigs are prepared by clipping the hair from a portion of the internal surface of the left thigh, the bared site being afterwards cleansed with methylated spirit. The site of the inoculation having been prepared, the animal is securely held by an assistant, who controls the three legs other than the one in which inoculation is to take place. The person making the inoculation grasps the thigh of the fourth leg in his left hand, close to the proposed site of inoculation, inserts the needle under the skin, and injects 1·5 ml. of the prepared solution into the subcutaneous tissue. The needle is then withdrawn and the thumb of the left hand pressed over the site of inoculation to prevent any exudation of the emulsion. The remaining 1·5 ml. is injected into a second guinea-pig of similar size and weight. An identification card is prepared, setting out particulars of the animals used and date of inoculation.

Unless the animals previously succumb or obvious signs of infection become apparent, the first guinea-pig is killed at the expiration of six weeks and a detailed post-mortem examination carried out. The site of inoculation and local glands, together with the liver and spleen, are examined for tuberculous lesions. If any lesions are present, smears of these should be made on clean glass slides. The smears are stained with heated carbol fuchsin for fifteen minutes, after which the stain is washed off. The slide is given repeated immersions in a bath of 20 per cent. sulphuric acid until decolorisation is complete, the smear remaining faintly pink after the final washing. The smear is then treated with alcohol for two minutes and again washed. Counter-staining with Loeffler's methylene blue or with 1 per cent. malachite green is next carried out for at least thirty seconds. The slide is given a final washing and is dried. It is advisable to treat slides with ether for some hours, to remove the fat. The bacilli will show as bright redrods, while the background of tissue cells and other organisms is stained blue or greenish blue, when the slide is microscopically examined. If a negative result is obtained, the second pig is killed after a further two weeks and the

same procedure adopted. This method is subject to considerable variation as to detail, but has been found satisfactory in practice. The great disadvantage of this type of identification is the time taken to arrive at a definite conclusion, the delay preventing possible administrative action being quickly taken.

Acidity Test for Cream

It is occasionally necessary to determine the *acidity* of cream in the laboratory. For this purpose, 9 grams of cream are weighed out into a white porcelain cup, an equal volume of distilled water being added. Five drops of phenolphthalein indicator are then added to the mixture. The mixture is titrated to a permanent pink tint by the slow addition of $\frac{N}{10}$ caustic-soda solution, stirring being carried out continuously. The quantity of caustic-soda solution required to neutralise the acid is recorded. The formula for calculating the percentage of acidity is:

$$A = \frac{B \times 0.009}{9} \times 100$$

where A = percentage of acidity, and

B = quantity of caustic soda used.

It should be noted that 1 ml. of $\frac{N}{10}$ caustic-soda solution neutralises 0.009 gram of lactic acid.

Chemical Examination

Samples of cream for chemical examination should be collected in the manner already described on page 56, and should be analysed as quickly as practicable. The interval between collection and examination should in no case exceed three days. Each sample should be mixed by shaking, pouring, or stirring until the cream pours readily, when a uniform emulsion can be secured. If the sample is excessively thick, it should be slightly warmed and then mixed. Care should be taken to avoid overheating the sample, as the cream may then "oil off." This precaution is especially necessary with thin cream.

The examinations usually carried out in chemical laboratories are as follows:

(1) Fat Percentage.
(2) Total Solids.
(3) Added Water.
(4) Ash.
(5) Total Nitrogen.
(6) Lactose.
(7) Gelatine.
(8) Preservatives.
(9) Colouring Matters.
(10) Resazurin Test.

(1) **Fat Percentage.**—The two methods for ascertaining the butter-fat percentage present in cream (in common use) are:

(a) The Gerber Method.
(b) The Roese-Gottlieb Method.

(a) *Gerber Method.*—One gram of cream is weighed into a standard milk butyrometer. Ten millilitres of warm distilled water, 10 mls. of sulphuric acid (s.g. 1·1815), and 1 ml. of amyl alcohol are added and the tube is stoppered. The mixture is well shaken until the curd is thoroughly dissolved. After centrifuging, the fat column is read, the percentage of fat being calculated by means of the following formula:

$$\text{Percentage} = \frac{10·92\text{R} + 0·46}{\text{W}}$$

where R = butyrometer reading.

      W = weight of cream used.

(b) *Roese-Gottlieb Method.*—One gram of well-mixed cream is weighed into a Gottlieb extraction apparatus. Eight millilitres of distilled water are well mixed, after which 1 ml. of concentrated ammonia solution is added and the whole again well mixed. Ten millilitres of 95 per cent. alcohol are now added with a further shaking, followed by 25 mls. of ether. The apparatus is then stoppered with a wetted cork and shaken vigorously for thirty seconds. The stopper is then carefully removed to avoid any loss and 25 mls. of petroleum ether added. The stopper is replaced, the whole is given a further shaking, after which the mixture is allowed to stand for about twenty minutes until the upper layer is perfectly clear. The top layer is siphoned off into a wide-necked flask and washed through with a further 5 mls. of ether. The subsequent procedure is similar to that described for ice-cream, already detailed on page 56.

(2) Total Solids.—The procedure necessary to estimate the percentage of total solids is similar to that described in the case of ice-cream (see page 57), except that 2 to 3 grams of cream are used instead of the former product.

(3) Added Water.—The *freezing-point test* is used in the majority of analytical laboratories for the detection of added water in cream. The freezing-point of undiluted cream is determined by the *cryoscopic method* and is generally accepted to be —·550° C. The addition of water brings the freezing-point more close to zero.

The freezing-point apparatus now commonly used owes its present form to an American chemist, Hortvet. Hortvet has designed an apparatus for carrying out the test, in which conditions and procedure are standardised, so that, for practical purposes, any correction factors may be omitted. This instrument has been adopted by most public analysts in this country and is now the most reliable means available for the detection and determination of added water in cream. The apparatus is simple in design and application.

The *Hortvet Cryoscope,* illustrated in Fig. 36, consists of a cylindrical vacuum flask surrounded by a metal casing to ensure a constant temperature. The neck of the flask is closed by a large cork, through which passes a metal tube holding the freezing tube; a metal inlet tube, the lower end of which is in the form of a perforated loop reaching almost to the base of the flask; a metal T-shaped tube; apertures for the gauge tube; and a control thermometer. A standard thermometer reading from 1° C. to 2° C. below zero is also fitted through the rubber stopper of the freezing tube. A metal stirrer is fitted through the same stopper, which has a third aperture for the insertion of the freezing starter. An air-drying apparatus connected to a rubber bellows is fitted on the right of the cryoscope, while, on the left, is

a drain tube for the collection of the vapours. An adjustable lens is fitted to magnify the thermometer readings, the entire apparatus being mounted upon a wooden stand. A scale is fitted to the stand showing percentages of added water.

Sufficient strong sulphuric acid is placed in the air-drying tube to cover the bulb, while 400 mls. of ether, previously cooled to 10° C. or lower, are poured into the T-shaped tube. This tube is then closed by a small cork, and air is passed through the apparatus by means of small rubber bellows until the control thermometer registers 3° C. below zero. The gauge tube is lowered into the ether bath, the top closed with the forefinger, and the quantity of ether necessary to restore the 400 mls. volume estimated. It will usually be found that 10 to 15 mls. suffice for this purpose. The necessary quantity of ether is next added, a small quantity of alcohol being also poured into the metal tube. Some 30 to 35 mls. of cream, previously cooled to 10° C. (sufficient to cover the bulb of the thermometer), are then placed in the freezing tube, which is inserted in the metal tube. The stirrer is kept in motion in a longitudinal direction at the rate of one stroke per second. Air is passed through the apparatus to maintain the temperature of the cooling bath at 3° C. below zero. Super-cooling of the sample will take place at approximately 1° C. below freezing-point. When this temperature is reached, it is often necessary to insert the freezing starter with a small quantity of ice, when a rapid rise in the mercury column will result. The stirrer is operated slowly several times as the mercury column approaches its highest point, the upper end of the thermometer being tapped lightly until the mercury column remains stationary for at least one minute. The reading of the thermometer is noted and estimation to 0·001° C. made. The percentage of added water is determined by comparison with the scale fitted on the stand. Broadly speaking, each 0·01° C. indicates approximately 2 per cent. of added water. The formula for determining the definite percentage of added water is:

By courtesy of Sutherland Thomson & Co.

FIG. 36—Hortvet Cryoscope

$$W = \frac{100 \ (T - T^1)}{T}$$

where W = percentage of added water.

      T = freezing-point of undiluted cream (— 0·550° C.).

      T^1 = freezing-point of sample.

(4) **Ash.**—To obtain the percentage of ash, 20 mls. of cream are placed in a weighed dish and the whole is reweighed. Six millilitres of nitric acid are then added, the contents being evaporated to dryness. The contents are next ignited at a temperature below redness, to free the ash of

the carbon which it contains. The dish and contents are finally cooled in a desiccator, and weighed. This weight, less the known weight of the dish, gives the weight of the ash, when the total percentage of ash contained in the sample may be readily calculated.

(5) **Total Nitrogen.**—The percentage of nitrogen in a sample of cream is determined by *Kjeldahl's method*, described on pages 57 to 58. Five grams of the sample are used for this purpose. To obtain the equivalent percentage of proteins, the percentage of nitrogen is multiplied by 6·38.

(6) **Lactose.**—This may be carried out in a manner similar to the process for cane sugar in condensed milk, except that only the direct rotation is necessary, and the lactose is calculated from that (see Chapter V).

(7) **Gelatine.**—The test used to determine the presence of gelatine in cream is similar to that made use of in the case of ice-cream, as set out on page 58.

(8) **Preservatives.**—The addition of preservatives to cream is now definitely forbidden by the Public Health (Preservatives, etc., in Food) Regulations, 1927, and it may therefore be necessary to test samples for the presence of any of the following substances:

(*a*) Formaldehyde.
(*b*) Salicylic Acid.
(*c*) Benzoic Acid.
(*d*) Boric Acid.

(*a*) *Formaldehyde.*—*Leach's test* for determining the presence of this substance in cream is simple and conclusive. Ten millilitres of cream are mixed in a porcelain dish with an equal volume of hydrochloric acid containing 1 ml. of a 10 per cent. ferric chloride solution for each 500 mls. of acid. The mixture is slowly heated to 80° to 90° F., the dish being rotated in order to break up the curd. A violet coloration denotes the presence of formaldehyde.

(*b*) *Salicylic Acid.*—Although this substance is not commonly used as a preservative owing to the taste which it imparts, it may be necessary to investigate its presence. For this purpose, 100 mls. of cream are acidified with 5 mls. of hydrochloric acid. The mixture is thoroughly shaken until curdling takes place, when it is filtered and treated with 50 to 100 mls. of ether. The ether layer is washed with two 5-ml. portions of water, and the greater bulk of the ether evaporated in a porcelain dish over a steam bath. The remainder is allowed to evaporate spontaneously, when a drop of 0·5 per cent. neutral ferric chloride solution is added. A violet coloration indicates the presence of salicylic acid.

(*c*) *Benzoic Acid.*—One hundred millilitres of cream are acidified, filtered, and extracted with ether, as in the case of the salicylic acid test. If benzoic acid is present in any quantity, the acid will crystallise from the ether in shining leaflets which have a characteristic odour when warmed. Half of the crystalline deposit should be dissolved in hot water and rendered alkaline by the addition of a few drops of ammonium hydroxide. The excess of ammonia is expelled by evaporation and the residue dissolved in several millilitres of hot water. If necessary, this solution may be filtered and several drops of neutral 0·5 per cent. ferric chloride added. A brownish precipitate denotes the presence of benzoic acid. The latter method constitutes the more delicate test.

(d) *Boric Acid.*—Twenty-five millilitres of cream are rendered alkaline by the addition of lime-water, the solution being evaporated to dryness. The residue is ignited at a low red heat until the organic matter which it contains is thoroughly charred. The residue is then cooled, digested with 15 mls. of water, and hydrochloric acid added drop by drop until the solution is distinctly acid. A piece of turmeric paper is saturated with the solution and allowed to dry at room temperature. If borax or boric acid is present, the paper will acquire a characteristic red colour, which in turn is changed by caustic soda to a dark blue-green tint. The red coloration is restored by the addition of acid.

(9) Colouring Matters.—Determination of the presence of *annatto* in cream is carried out in a similar manner to that described for ice-cream on page 58.

(10) Resazurin Test.—This test should be applied to all milk purchased for separation purposes in the manner briefly set out on page 59.

LEGISLATIVE CONTROL

A multiplicity of legislation governs the production and sale of milk with which is included cream, since this article is a constituent of the former product. Added to this is the legislation dealing with the sale of foods for human consumption.

The various Acts, Orders, and Regulations appertaining to this matter are tabulated below, together with the specific sections or Articles which apply thereto.

Act or Order	*Section or Article Applying*
Public Health (Prevention of Tuberculosis) Regulations, 1925	4, 5, 6, 7
Public Health (Preservatives, etc., in Food) Regulations, 1925	4, 6, 11
Milk and Dairies Order, 1926	4, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 26, 27, 28, 29, 31 (2), 32
Public Health (Infectious Disease) Regulations, 1927	10, 11. Schedule 1 (Part 3)
Public Health Act, 1936	149
Food and Drugs Act, 1938	1, 2, 3, 17, 18, 22, 23, 24, 25, 40, 41, 42, 68, 69, 70, 71
Tuberculosis Order, 1938	2 (3)
The Cream (Production and Sales) Order, 1940	Whole Order
Milk and Dairies Regulations, 1943	21

All superfluous matter has been omitted from the details of the legislation set out in the following pages.

Public Health (Prevention of Tuberculosis) Regulations, 1925

Definitions : "Milk" means milk (including cream, skimmed milk, and separated milk) intended for sale for human consumption.

"Dairy" includes any farm, cowshed, milk store, milk shop, or other place from which milk is supplied on, or for, sale, but does not include a shop or other place in which milk is sold for consumption on the premises only.

Employment of Persons suffering from Tuberculosis.—Article 4. No person who is aware that he is suffering from tuberculosis of the respiratory tract shall enter upon any employment or occupation in connection with a dairy which would involve the milking of cows, the treatment of milk, or the handling of vessels used for containing milk.

Stoppage of Employment.—Article 5. Notwithstanding anything contained in the Public Health (Tuberculosis) Regulations, 1912, if a Local Authority on the report in writing of their Medical Officer of Health are satisfied that a person residing in their district who is engaged in any such employment or occupation as aforesaid is suffering from tuberculosis of the respiratory tract and is in an infectious state, they may by notice in writing signed by the Clerk or the Medical Officer of Health require such person to discontinue his employment or occupation on or before the day specified in the notice, such date being not less than seven days after the service of the said notice.

Right of Appeal.—Article 6. Allows an aggrieved person the right of appeal to a court of summary jurisdiction.

Compensation.—Article 7. Provides for compensation to be paid to person sustaining damage owing to application of the powers of Article 5.

Public Health (Preservatives, etc., in Food) Regulations, 1925-7

Articles 4 (1) and 6 (1) and (2), which deal with the prohibition of preservatives in food, have already been dealt with on pages 60 and 61.

Definition : "Cream" means that portion of milk rich in milk-fat which has been separated by skimming or otherwise and is intended for human consumption.

Addition of Thickening Substances to Cream Prohibited.—Article 4 (3). No person shall sell cream which contains any thickening substance.

Prohibition of Preservatives in Imported Food.—Article 11 (1) Prohibits the importation of cream containing preservatives or added colouring matter.

Prohibition of Thickening Substances in Imported Cream.—(2) Prohibits the importation of cream for future sale which contains any thickening substance.

Milk and Dairies Order, 1926

This Order was made under Acts now repealed but its operation is continued by the Food and Drugs Act, 1938. In many respects, the provisions are not sufficiently comprehensive, while some clauses are so indefinite as to allow of a wide difference of opinion as to their requirements. Consequently, any appeal to the courts is a matter of conjecture.

Definitions : "Milk" means milk intended for sale for human consumption or for use in the manufacture of products for sale for human consumption, and includes cream, skimmed milk, and separated milk.

The reference in this definition to the word "sale" should be noted. This has the effect of limiting the application of most of the provisions of the Order.

"Infectious Disease" means any infectious disease to which the interpretation in Section 343 of the Public Health Act, 1936, applies.

"Cowkeeper" means any person who keeps one or more cows for the purpose of the supply of milk.

"Dairy" includes any farm, cowshed, milk store, milk shop, or other place from which milk is supplied on, or for, sale, or in which milk is kept or used for the purposes of sale or manufacture into butter, cheese, dried milk, or condensed milk for sale, and, in the case of a purveyor of milk who does not occupy any premises for the sale of milk, includes the place where he keeps the vessels used by him for the sale of milk, but does not include a shop from which milk is not supplied otherwise than in properly closed and unopened receptacles in which it was delivered to the shop or a shop or other place in which milk is sold for consumption on the premises only.

"Registered Premises" means any building or other premises required to be registered under the provisions of this Order.

Duty of Employers to make known Terms of Order to Employees.—Article 4. Provides that all cowkeepers and dairymen must take all practicable steps to make known the provisions of the Order to their employees.

Keeping of Registers.—Article 6 (1). Every sanitary authority to keep registers of all cowkeepers or dairymen and of farms and other premises used as dairies.

When the Food and Drugs (Milk and Dairies) Act, 1944, comes into operation, registration of producers will be transferred to the Minister of Agriculture, and this Article should now be read in the light of such alteration.

It should be noted that all retail purveyors of cream, irrespective of the manner in which it is sold, must be registered, whether or not they occupy premises in the area of the registering authority. No Local Authority can refuse to register premises other than those of retail purveyors. Shops selling cream in sealed cartons must be considered and registered as "retail purveyors."

(2) Subject to the provisions of any statutory enactment, the sanitary authority, on the application of any person proposing to carry on in their district the trade of cowkeeper or dairyman or to use any farm or other premises in the district as a dairy, shall register such person or premises.

(3) Provides that no person shall carry on the trade of cowkeeper or use any premises as a dairy unless he and any premises are registered.

Notice of Use of New Building.—Article 7. One month's notice to be given to the sanitary authority of the occupation or use of a cowshed or place for the keeping of milk.

Articles 8, 9 and 10 have been repealed by Article 3 of the Milk and Dairies (Amendment) Order, 1938. This step was rendered necessary by the transfer of the functions of veterinary inspection from Local Authorities to the Minister of Agriculture and Fisheries under Section 19 (1) of the Agriculture Act, 1937.

Health of Animals.—Article 11. The following diseases, affecting cows, now set out in the First Schedule, Part 1, of the Food and Drugs Act, 1938, shall be diseases for the purpose of this Article. These are:

Acute mastitis.
Actinomycosis of the udder.
Suppuration of the udder.
Anthrax.
Foot and mouth disease.
Any comatose condition.
Any septic condition of the uterus.
Any infection of the udder or the teats which is likely to convey disease.

Provides also for the service and withdrawal of notices regarding any animal or animals and for appeal by owner of such animal or animals to the Local Authority.

Windows and Lighting.—Article 12 (1). Provides for the lighting and ventilation of cowsheds and buildings used for the storage of milk.

The absence of any definite standard of window space in relation to floor area is a serious omission, while no minimum area for ventilation openings is prescribed.

Lighting (Artificial).—(2) Provides for the adequate artificial lighting of cowsheds and other buildings where milk is stored.

Water Supply.—Article 13. (1) All registered premises shall be provided with a supply of water suitable and sufficient for the requirements of this Order.

The word "suitable" is indefinite and liable to lead to argument as to the suitability of a particular supply. The Order should have required a pure, wholesome and sufficient supply.

Cleansing of Receptacles.—(2) Provides for the cleansing of all receptacles used for the conveyance and storage of water.

Prevention of Contamination.—(3) States that all water supplies used for the watering of the animals shall be protected from contamination as far as reasonably possible.

No mention is made of a *pure* water supply in this Section and the wording allows too much latitude in respect of water supplies generally. Attention is drawn to the phrase "as far as reasonably possible," and to the fact that provision is not made to guard against *every* kind of contamination.

Storage of Milk.—Article 14. (1) Milk shall not be deposited or kept in any place where it is liable to become contaminated or infected. In particular it shall not be deposited or kept:

(i) In any room used as a kitchen, scullery, living-room, or sleeping-room; or
(ii) In any room or part of a building which communicates directly by door, window, or otherwise with:
   (a) Any water-closet, earth-closet, privy, cesspool, or receptacle for ashes or other refuse; or
   (b) Any room which is used as a sleeping-room or any room which is occupied by a person suffering from an infectious disease, or which, having been so occupied, has not been subsequently properly disinfected; or
(iii) In any room or part of a building in which there is any direct inlet to a drain which is not sufficiently trapped;

Provided that the foregoing provisions shall not be deemed to prohibit the deposit or keeping of milk intended for use in the manufacture of butter, cream, or cheese in a room used as a kitchen.

(2) Vessels to be properly covered and milk protected from all sources of contamination.

(3) No foul or noxious matter or soiled bed or body clothing to be conveyed through any part of a building used for the keeping or storage of milk.

No mention is made of any gas, vapour, effluvia or other odoriferous articles likely to taint milk.

Cleanliness of Persons Handling.—Article 15. All persons handling milk to keep their clothing and persons in cleanly condition.

Processes to be carried out free from Contamination.—Article 16. All processes to be carried out free from the danger of contamination and appliances to be stored in such a manner as to be free of contamination.

Notification of Infectious Disease in Family of Milker, etc.—Article 17. (1) Every person having access to the milk or to the churns or other milk receptacles in or about any registered premises, as soon as he becomes aware that any member of his household is suffering from an infectious disease, shall immediately notify the occupier of such premises of the fact, and the occupier shall immediately notify the Medical Officer of Health of the district in which the premises are situated unless notification has already been given to that officer.

L.A. to Notify Adjoining L.A.—(2) Where the Medical Officer of Health of any sanitary district becomes aware that any person is suffering from an infectious disease or has recently been in contact with a person so suffering, he shall forthwith notify the occupier of the premises of the fact and where the council of such sanitary district are not the registering authority for the locality in which the premises are situate, they also must notify the Medical Officer of the registering authority.

Stoppage of Milk Supply in case of Infectious Disease.—Article 18. (1) If the Medical Officer of Health believes that infectious disease is being caused by any milk supply, notice may be served on the producer or retailer stopping the supply of milk or the sale thereof.

Period of Notice.—(2) Notice operates for twenty-four hours and may be renewed for further similar periods.

Duty of M.O.H.—(3) Medical Officer must report the service of any notice to the sanitary authority and if premises are within his district must endeavour to ascertain the causes of the infectious condition of the milk.

(4) If the milk is obtained from outside his district, the Medical Officer must serve a copy of the notice upon the Medical Officer of the district in which the premises are registered.

Offence.—(5) Makes it an offence to sell milk for human consumption or for manufacturing purposes contrary to the terms of the notice previously mentioned.

Compensation.—(6) Provides for compensation for loss or damage sustained owing to such a notice.

Examination of Cases and Contacts. Stoppage of Employment.—Article 19. (1) Provides for the examination of all cases and also for contacts at premises where milk is dealt with or handled.

(2) If any person is found who is likely to infect the milk or lead to the spread of infectious disease, person may be prohibited from handling milk or utensils for a specified period.

(3) Provides that a person on whom such notice is served shall not handle any milk or utensils for the period specified, or until the danger of the spread of infection has ceased.

(4) Employer must not allow the person specified to handle milk or utensils until the period specified has expired or until danger of infection has ceased.

Keeping of Pigs, and Poultry, etc.—Article 20. Pigs or poultry not to be kept in any dairy or cowshed or in any room adjoining same.

Article 21 has now been repealed and amended by the Milk and Dairies Regulations, 1943. The Article, as altered, is set out on page 112.

Articles 22, 23, 24, and 25 deal with the following subjects:

(1) Cleanliness of cowshed.

(2) Deals with the milking of cows, cleanliness of milking stools, removal of milk from cowshed and bedding.

(3) Cooling of milk.

(4) Construction of floors and standings of cowsheds.

Furniture and Fittings.—Article 26. Provides that the furniture and fittings of buildings used for the sale of milk shall be cleansed as often as necessary. Floor to be constructed of impervious material in order that all liquid matter may drain away and to be washed down at least once daily.

The Order is decidedly inadequate and indefinite regarding the provision of a dairy or milk room. While certain conditions as to lighting, ventilation, floors, etc., are prescribed, no mention is made of separate storage room apart from the washing room.

Cleansing of Receptacles.—Article 27. No churn vessel, or receptacle shall be used for the reception, measurement, storage, or delivery of milk unless the interior surface is capable of being readily cleansed.

Cleansing of Churns, etc.—Article 28. Churns and receptacles to be cleansed by consignee before they are returned to the owners.

Labelling and Sealing.—Article 29. All receptacles other than bottles to have the name and address of the owner permanently marked thereon. Lids of churns and other receptacles to be constructed so as to prevent the entrance of dust, dirt, or rainwater to the milk.

Opening of Churns, and Bottles.—Article 31. Churns not to be opened in transit except for the purpose of checking the contents and the taking of samples.

Bottles to be filled and closed only on registered premises and not to be opened again prior to delivery to the consumer.

Prevention of Contamination.—Article 32. Milk to be protected from effects of heat and from contamination by dirt, dust, and rainwater.

No provision is made for preventing the contamination of milk by storage in proximity to any odoriferous matter.

Public Health (Infectious Disease) Regulations, 1927

Under these Regulations, any person suffering from typhoid fever, paratyphoid fever, or dysentery, or any "carrier" of such diseases, may be excluded from any occupation connected with the preparation or handling of food and drink. The full text of the relevant Articles and Schedule has already been set out on pages 61 and 62.

Public Health Act, 1936

Section 149 which deals with the spread of specified notifiable diseases has already been detailed in Chapter I, page 62.

Food and Drugs Act, 1938

Sections 1, 2 and 3, which deal with the adulteration of an article of food and its sale, have already been dealt with in Chapter I, page 64. Sections 17 and 18, dealing with food poisoning, are set out on page 66.

Definitions: "Milk" includes cream.

"Cream" means that part of milk rich in fat which has been separated by skimming or otherwise.

"Dairy" includes any farm, cowshed, milk store, milk shop, or other premises from which milk is supplied on or for sale, or in which milk is kept or used for the purposes of sale or of manufacture into butter, cheese, dried milk, or condensed milk for sale, or in which vessels used for the sale of milk are kept. Does not include a shop from which milk is sold in sealed containers or where milk is consumed on the premises.

"Dairyman" includes an occupier of a dairy, a cowkeeper, and a purveyor of milk.

Power to Refuse or Cancel a Registration. Section 22. (1) If it appears to an Authority by whom dairymen are registered that the public health is or is likely to be endangered by any act or default of a person who has applied to be or who is so registered by the Authority, being an act or default committed whether within or without the district of the Authority in relation to the quality, storage, or distribution of milk, they shall serve on him a notice stating the place and time, not being less than seven days after the service of the notice, at which they propose to consider the matter and informing him that he may attend before them together with any witnesses he may desire to call at the time and place mentioned, to show cause why registration should not be refused or his registration should not be cancelled either generally or in respect of any specified premises.

(2) If the person on whom the notice has been served is unable to satisfy the Authority, they may either refuse to register him or cancel his registration as the case may be and shall forthwith give him notice of their decision and shall, if required by him within fourteen days of their decision, give him within forty-eight hours, a statement of the grounds on which their decision is based.

Appeal.—(3) Person aggrieved may appeal to a court of summary jurisdiction.

Cancellation of Registration following Conviction.—(4) A court before which a person registered as a dairyman otherwise than by the Minister of Agriculture and Fisheries is convicted of any offence against this Act or under any Milk and Dairies Regulations may, in addition to any other penalty, cancel his registration.

Information as to previous Registration.—(5) An Authority other than the Minister of Agriculture and Fisheries, may require any person who applies for registration as a dairyman to give them, before his application is considered, information as to whether he is or has been registered as a dairyman whether by them or by the Minister of Agriculture and Fisheries or some other Authority. The applicant is guilty of an offence if the information supplied by him is false.

No Liability for Breach of Contract.—(6) If a person's application for registration as a retail purveyor of milk is refused or if his registration is cancelled, he

shall not be liable for breach of contract for the purchase of further supplies if such refusal or cancellation was due to the quality of milk supplied by the person with whom he holds the contract to take supplies.

It is important to remember that the day on which it is decided to serve a seven days' notice under (1) above must not be included in the period of the notice.

Removal of a Retailer from the Register

The course to be taken in removing a retailer from the register is generally as follows:

(*a*) A report is presented by the Medical Officer of Health or Sanitary Inspector drawing attention to any act or default on the part of the retailer and showing in what respect the public health is or is likely to be endangered.

(*b*) The Authority consider the matter and then serve notice upon the retailer as to the time and place where the matter is to be considered, informing him that he may call witnesses on his behalf. At least seven days' notice should be given.

(*c*) If the retailer fails to satisfy the Authority when he appears before them, they must give him notice of their decision in the matter forthwith.

(*d*) If required to do so by the retail purveyor within fourteen days of their decision, the Authority must, within forty-eight hours, state the grounds on which their refusal is based.

(*e*) The retail purveyor if aggrieved may then appeal to a court of summary jurisdiction.

(*f*) Either the Authority or the retail purveyor may appeal further to a Court of Quarter Sessions.

It should be observed that the above procedure is carried out in respect of refusal to register a retail or wholesale purveyor of milk. Refusal to register or removal from the register may either be absolute or in respect of certain specified premises. This enables the Authority or the court to distinguish between cases in which the defect is one of general methods or those in which it has relation only to the suitability of particular premises or methods practised thereat.

Regulations re *Adulteration of Milk.*—Section 23. The Minister of Agriculture and Fisheries may make regulations as to the presumptive evidence of the adulteration of milk.

Certain Additions not to be made to Milk.—Section 24. States that:

(*a*) No water, colouring matter, any dried or condensed milk or liquid reconstituted therefrom shall be added to milk intended for sale for human consumption.

(*b*) No unseparated milk or mixture of cream and separated milk shall be added to unseparated milk intended for such sale, or

(*c*) Sell or offer or expose for sale or have in his possession for purposes of sale, for human consumption, any milk to which such additions have been made.

(*d*) No person shall sell, offer, or expose for sale as milk any liquid to which separated, dried, or condensed milk has been added.

Prohibition of Sale of Tuberculous Milk, etc.—Section 25. (1) No person shall sell, offer or expose for sale for human consumption or use in the manufacture of products for sale for human consumption the milk of any cow which to his knowledge has given tuberculous milk or is suffering from emaciation due to tuberculosis or from tuberculosis of the udder or any other disease of cows to which this Section applies.

(2) In any proceedings under this Section, the defendant shall be deemed to have known that the cow had given tuberculous milk or was suffering as aforesaid if he could, with ordinary care, have ascertained the fact.

The diseases of cows to which this Section applies, in addition to tuberculosis, are those specified in Part I of the First Schedule of the Act

and include any other disease which may be added by any subsequent Milk and Dairies Regulations. These are:

    (*a*) Acute mastitis.
    (*b*) Actinomycosis of the udder.
    (*c*) Suppuration of the udder.
    (*d*) Any infection of the udder or teats which is likely to convey disease.
    (*e*) Any comatose condition.
    (*f*) Any septic condition of the uterus.
    (*g*) Anthrax.
    (*h*) Foot and mouth disease.

It should be noted that contagious abortion is not specifically mentioned but no doubt this is meant to be dealt with under (6) above.

Restrictions on Importation.—Section 40 (*b*) Makes it an offence to import any adulterated or impoverished milk except in containers conspicuously marked with a name or description indicating that the milk has been so treated.

Sampling of Imported Foods.—Section 41. Provides powers for sampling of imported foods by Customs Officers.

Penalties.—Section 42. Provides penalties for any offence under Section 40.

Sections 68, 69 and 70 already detailed on page 67 give powers of sampling and prescribe methods of dividing such samples. As regards Section 68, the following additional Sub-sections have special reference to milk *and* cream.

(5) Where milk sold or exposed for sale within the area of any council is obtained from a dairy situate outside that area, the Medical Officer of Health or any other authorised officer of the council may, by notice in writing to the Medical Officer of Health or other authorised officer of a Food and Drugs Authority within whose area the dairy is situated, or through whose area the milk passes in transit, request him to procure samples of milk at that dairy or while it is in transit and it shall be the duty of an officer who receives such a notice to procure, as soon as practicable, samples of the milk in question and forward the samples to the officer who gave the notice or to such person as the officer may direct and the samples so procured shall be deemed to have been obtained within the area for which the last-mentioned officer acts.

(6) An authorised officer may procure samples outside his own area if the Authority of that area where the samples are to be taken does not object. Such consent is not to be unreasonably withheld.

(9) Any officer taking samples in course of transit by rail shall conform to such reasonable requirements of the railway company as to prevent any obstruction in railway working.

Special provisions as to milk are set out below.

Special Provisions as to Milk.—Section 71 (1). The provisions of this Act relating to the procuration of samples of milk are subject to the provisions set out in the Third Schedule of the Act.

(2) It is a defence for any defendant charged with an offence under this Act or any Food Regulations or Milk and Dairies Regulations in respect of a sample of milk taken after it has left his possession if he can prove that the churn or other vessel containing the milk was effectively closed and sealed at the time it left his possession but had been opened before the person taking the sample had access to it.

Special Provisions as to the Sampling of Milk

(1) Where a sample of milk is procured from a purveyor of milk, he shall, if required to do so by the person by whom or on whose behalf the sample was procured, state the name and address of the seller or consignor from whom he received the milk.

(2) Within sixty hours after the sample was procured from the purveyor he may serve on the Authority by whose officer it was procured, or, if it was not procured by an officer of any Authority, on the Food and Drugs Authority

within whose area it was procured, a notice stating the name and address of the seller or consignor from whom he received the milk and the time and place of delivery to himself of milk from a corresponding milking, and requesting the Authority to take immediate steps to procure, as soon as practicable, a sample of milk from a corresponding milking in the course of transit or delivery to himself from the seller or consignor.

Provided that:

(a) if such a sample has been so procured since the sample in question was procured, or had been so procured within twenty-four hours prior to that sample being procured, it shall not be necessary for the Authority to procure another sample in accordance with the notice: and

(b) the purveyor shall have no right to require that such a sample shall be procured if the milk from which the sample procured from him was taken was a mixture of milk obtained by him from more than one person.

(3) If the purveyor has served on the Authority such a notice as aforesaid and the Authority have, in a case not falling within proviso (a) to the preceding paragraph, omitted to procure a sample of milk from the seller or consignor in accordance with the foregoing provisions, no proceedings under this Act shall be taken against the purveyor in respect of the sample procured from him.

(4) Any sample so procured in the course of transit or delivery shall be submitted for analysis to the analyst to whom the sample procured from the purveyor is or was submitted.

(5) If proceedings are taken against the purveyor, a copy of the certificate of the result of the analysis of every sample so procured in the course of transit or delivery shall be furnished to him and every such certificate or copy shall, subject to the provisions of Section 81 of this Act (Evidence of Certificates of Analysis and presumptions), be admissible as evidence on any question whether the milk sold to the purveyor was sold in the same state as it was when he purchased it.

(6) The Authority by whose officer, or within whose area the first-mentioned sample was procured may, instead of, or in addition to, taking proceedings against the purveyor, take proceedings against the seller or consignor.

· (7) If a sample of milk of cows in any dairy is procured in course of transit or delivery from that dairy, the dairyman may, within sixty hours after the sample was procured, serve on the Authority by whose officer the sample was procured a notice requesting them to take immediate steps to procure as soon as practicable a sample of milk from a corresponding milking of the cows and thereupon paragraphs (2) to (5) of this Schedule shall, so far as applicable, apply with any necessary modifications.

Provided that the person procuring the sample shall be empowered to take any such steps at the dairy as may be necessary to satisfy him that the sample is a fair sample of the milk of the cows when properly and fully milked.

Tuberculosis Order, 1938

Definitions: "Milk" includes cream and separated or skimmed milk.

"Tuberculous emaciation" means emaciation due to tuberculosis.

As regards milk, the Order states:

(1) The milk from any animal affected with chronic disease of the udder or tubercular emaciation or is suffering from a chronic cough or shows definite clinical signs of tuberculosis shall not be mixed with other milk until the animal has been examined by a veterinary surgeon.

(2) The milk must not be mixed with other milk until after six weeks have expired to enable microscopical and biological tests to be carried out if these are considered necessary and until the owner has been notified that this is no longer necessary.

(3) All such milk must be effectively boiled or sterilised and all utensils which have come into contact with such milk shall be effectively sterilised either with steam or boiling water before any other milk is placed therein.

Notice is served on the owner, in the case of any suspected animal, for its isolation and prohibiting the mixing of the milk.

Cream (Production and Sales) Order, 1940

This Order became operative in October, 1940, and from that date the manufacture, sale or purchase of cream was prohibited. This ban also included cream cheese and ice-cream containing cream. The provisions of the Order do not apply to the manufacture or use of cream for household consumption or its manufacture or sale for the making of butter. No doubt this Order will be repealed when milk rationing ceases.

Milk and Dairies Regulations, 1943

Under these Regulations, Article 21 of the Milk and Dairies Order, 1926, is repealed, and the following Article substituted:

Article 21. Every cowkeeper or dairyman shall cause all vessels (including the lids of such vessels) and appliances used or intended to be used by him for containing, measuring, or stirring milk, or for any other purpose for which they may be brought into contact with milk, to be kept at all times in a state of thorough cleanliness.

For this purpose—
  (i) every such vessel, lid and appliance (except a mechanical milker or similar appliance used in milking which is efficiently cleansed before it is brought into contact with milk) shall be thoroughly washed as soon as may be after use, and shall be cleansed and scalded with boiling water or steam before it is used again;
 (ii) no oxidising or preservative agent other than such solutions of sodium hypochlorite as may from time to time be approved by the Minister of Agriculture and Fisheries shall be used in the cleansing of any such vessel, lid, or appliance and where such solutions so approved as aforesaid are used, all trace thereof shall be removed before such vessel, lid, or appliance is brought into contact with milk;
(iii) every such vessel, lid, and appliance when not in use shall be stored in a clean place and shall be protected from dust and dirt; and
 (iv) no such vessel or appliance shall be used for containing, measuring, or applying any process or treatment to any article other than milk or milk products.

This Article permits, as a war-time measure, the employment of sodium hypochlorite solutions specified by the Minister of Agriculture and Fisheries in addition to normal methods of sterilisation used, but nowhere is it stated that utensils should be sterilised, a process of extreme importance in ensuring the distribution of a clean product. Further, no control over the utensils employed for heating water used for cleansing purposes is provided, and there is nothing to prevent the domestic copper in which household linen has been boiled being used for this purpose. Sub-section 3 of this Article states that utensils should be stored in a clean place, but opinions as to what constitutes a clean place are likely to differ considerably, and a dairy or a milkroom should certainly have been specified as the place of storage.

CLOTTED CREAM

Introductory

A definite demand for clotted cream has existed for some considerable time, the manufacture of the article being chiefly centred in the south-west of England, more particularly in the counties of Somerset, Devon and Cornwall. There is no doubt that this article has been produced in this part of England for several hundred years, but there are exceedingly few references regarding it in scientific literature. Although the prohibition of the addition of preservatives to cream temporarily reduced the output,

improved methods of manufacture succeeded in overcoming the difficulties then experienced, and clotted cream up to the war was successfully prepared in many agricultural districts of this country. Large-scale manufacture had been commenced prior to the war and considerable developments were interrupted by the advent of hostilities. There is, however, little control over production, except in creameries.

Clotted cream was long considered a luxury, but has been widely recommended by the medical profession as an excellent fatty food, particularly for use in the dietary of invalids. Clotted cream is exceedingly rich, containing from 60 to 70 per cent. of fat. This fat is present in the cream in a finely emulsified condition, which renders it unusually digestible.

Methods of Manufacture

The use of milk possessing a high fat content is very desirable in the preparation of clotted cream. Milk produced by Jersey or Guernsey cattle is ideal for the purpose, as 1 lb. of cream may be obtained from $1\frac{1}{2}$ gallons of this milk. The evening milk from Shorthorn cattle yields approximately 1 lb. of cream from 2 gallons of milk, while the cream produced from such milk is of excellent quality. In Devon and Cornwall, clotted cream is largely manufactured from the milk of Devon cattle, crosses with Channel Islands cattle being also used.

When the cream contains a high percentage of fat, it is necessary to speed up the process, scalding taking place at a slightly higher temperature. Care must, however, be taken to ensure that the temperature is not excessive. If such is the case, the product will have a peculiar boiled taste and rough appearance and will exhibit a white-flaked surface. If the milk-fat is present in the form of large globules, the period required for the setting process should be shorter than that employed when the fat is present in the form of small globules. On the other hand, such milk must be heated to a higher temperature and must be retained for a longer period at this temperature.

The results of experiments conducted along these lines, using whole milk, are shown in the following table[1].

TABLE 8

Breed	Time setting before Scalding	Best Scalding Temperature	Correct Time of Scalding	Time standing before Skimming
	Hours	° F.	Minutes	Hours
Shorthorn	15	185	45	24
Lincoln Red Shorthorn	15	180	40	24
Devon	15	180	40	24
South Devon	14	185	45	25
Longhorn	14	190	45	22
Red Poll	17	185	40	24
Ayrshire	17	175	30	24
British Friesian	17	180	30	24
Jersey	14	195	50	26
Guernsey	14	190	50	26
Kerry	15	180	40	26
Dexter	15	180	40	26
Park	16	185	40	24

[1] Reproduced by permission of the Controller of H.M. Stationery Office from Bulletin No. 57 of the Ministry of Agriculture and Fisheries—*Butter, Cream Cheese, and Scalded Cream* (1933).

There is no standardised method of preparing clotted cream.   Several
systems are used, varying chiefly as regards the method of obtaining the
raw cream, and resulting in considerable variation in the texture, flavour,
and appearance of the finished article.   The flavour and physical consistency
of the cream are dependent upon:

(1) The acidity of the original milk.
(2) The temperature of scalding.
(3) The time allowed for scalding.

The several methods of manufacture in common use are:

(1) Earthenware Bowl Method.
(2) Shallow Pan System.
(3) Scalding over Separated Milk.
(4) Direct Scalding Method.

The last two mentioned methods make use of cream mechanically separated
from the original milk.   These methods are used with milk of unknown
or doubtful cleanliness, as such milk, if used with the first two systems,
may sour during the scalding process, when the cream will possess a poor
keeping quality.

(1) **Earthenware Bowl Method.**—This is the original method of preparing
clotted cream, having been carried out for several hundred years in the
farm-house dairies of south-west England.   The milk is placed in earthen-
ware bowls, which stand over water jackets.   The milk is allowed to stand
in order that the cream may rise, the conditions under which creaming
takes place exercising a direct influence upon the quality of the final
product.   The settled milk is gradually heated by means of the water
jacket, care being taken to ensure that the temperature does not reach
boiling point and that the cream layer is not disturbed in any way.   The
scalded milk is then allowed to cool without disturbance, a process which
necessitates the milk remaining overnight.   The layer of cream is removed
during the following morning by means of a skimmer.   This method is
not in general use to-day, having been superseded by one of the more
up-to-date processes to be described.

(2) **Shallow Pan System.**—Warm milk direct from the cow is strained
into setting pans.   The pans most suitable for the purpose will accom-
modate approximately $1\frac{1}{2}$ gallons of milk, and measure 15 inches across
the upper rim, some 10 inches across the base, with a depth of 7 to 9 inches.
The pans of milk remain standing in the dairy to allow the cream to rise.
The period necessary for this purpose varies according to the richness of
the cream and the season of the year.   It is usual for the morning's milk
to be scalded in the afternoon, while the evening's milk is either scalded
the same night or very early the following morning.

When the cream has risen, the pans are removed, care being taken not
to disturb the cream.   Scalding operations are then carried out.   The pans
are placed on a hot-water stove capable of dealing with two to six pans,
and steam is allowed to play upon them until the required temperature
is attained.   When the desired temperature has been reached, the pans
are allowed to stand in the heating agent for approximately twenty minutes,
and are then taken to the dairy to cool.   The optimum scalding temperatures
and period of scalding are set out in Table 8 on page 113.   When sufficiently
scalded, the cream will separate from the sides of the pan and will show

a definite crinkled appearance. Scalding can be carried out much more quickly during summer than winter.

Small producers often use a galvanised steaming pan, which is placed over a coal- or oil-stove. The water in the steamer is heated until boiling occurs, when the setting pan is placed over the steamer and the cream scalded. The pan is cooled quickly and is kept cool until the cream has been skimmed off. The period during which the pan is allowed to stand is usually twelve to twenty-four hours in summer and twenty-six to thirty-six hours in winter. The cream is removed by means of a perforated skimmer.

(3) **Scalding over Separated Milk.**—This has now become an exceedingly popular method, as it entails less labour than either of the processes already described. As the milk is separated immediately after milking, any risk of souring during hot weather is also obviated. The milk is separated immediately after removal from the cowshed, the separator being adjusted to yield a cream containing approximately 60 per cent. of fat. One quart of separated milk is placed in each setting pan, while 2 quarts of the separated cream are floated over the milk. The whole is scalded in the manner previously described, for fifty minutes at a temperature of 195° F. The pan is then removed and cooled. The cream is skimmed after eight to twelve hours. The resultant product possesses a pleasing flavour and excellent keeping qualities.

(4) **Direct Scalding Method.**—Separated cream is poured into shallow, jacketed pans, 4 inches in depth, and is scalded as previously described. The separation process is usually arranged in such a way that the cream possesses a higher fat content in summer than in winter. This is done in order to obtain the required consistency. To improve the flavour of the cream and to secure satisfactory keeping qualities, one-quarter of a tea-spoonful of castor sugar is generally added, the sugar being thoroughly mixed into the cream. The cream is stirred thoroughly during scalding for the first fifteen minutes, in order to aerate the product and to ensure a pleasing flavour. After scalding, the pans are removed and cooled in the manner previously described.

Cooling is extremely important. In the past, much clotted cream has become sour or bitter to taste due to the presence of lipolytic and proteolytic organisms. The main difficulty to be surmounted is bacterial multiplication during the slow cooling period which follows scalding operations. Accelerated cooling arrangements in a sterile atmosphere are essential, while the characteristic flavour and texture must be preserved.

All utensils, such as pans, separators, and skimmers, should be efficiently cleansed and sterilised, and should always be stored in a clean place.

The cream after skimming is worked together, and is, in the majority of cases, packed into cartons or tins for distribution. Considerable contamination during packing is much more probable than is the case when dealing with liquid cream, and extreme care must be taken to avoid it. Clotted cream is generally sold by weight.

CANNED CREAM

Considerable quantities of canned cream were sold annually in this country prior to the war, the greater proportion being imported from abroad. There is no doubt that these sales will be renewed when circumstances permit. The process of manufacture is briefly as follows. The

original milk is first mechanically separated and the acidity adjusted, sodium bicarbonate being added as a stabilising agent to prevent undesirable changes in consistency. The cream is then homogenised, the resulting product being subsequently filled into cans. The cans are exhausted, sealed, and sterilised at a high temperature, care being taken to ensure uniform heating of the cans and their contents. Canned cream generally possesses a flavour peculiarly its own, this being due to the processing which it undergoes, and while its viscosity is high, due to the homogenisation process, sterilisation spoils its whipping quality. The fat percentage is rather low, being usually in the neighbourhood of 20 to 30 per cent., the amount generally being stated on the label. These labels, however, are sometimes misleading, as cream with a low fat content, i.e. 20 to 25 per cent., may be described as "highly concentrated cream" or "rich cream." The solids-not-fat content may vary between 6·5 to 9·5 per cent.

Neutralising agents are sometimes added to canned cream to vary its consistency. The texture should be smooth. *Graininess*, which produces an undesirable lumpiness in the cream and cannot be shaken out, and *lumpiness*, which is difficult to remove by shaking, are two of the major defects found in this product. They may be removed, however, by the careful employment of neutralising agents. *Separation* is another defect in which a thin fluid serum is exuded. This is due to prolonged storage, and shaking will, in all normal instances, remove the defect, although in bad cases the cream will re-separate shortly after shaking is completed.

STERILISED CREAM

A method of sterilising cream without the development of chemical changes which cause caramelisation and instability was patented by Grindrod in the United States of America in 1939. The sterilised product exhibits extremely stable qualities, and the cooked flavour or burnt taste usually associated with excessive heating is almost completely absent. Creams with butter-fat percentages of 18, 20 and 30 have been produced by this method. Fresh cream with an acidity below 0·15 per cent. is used.

The cream used for processing is piped to a storage tank in the processing room, and approximately 0·10 to 0·25 per cent. by weight sodium alginate is added to act as a stabiliser, preventing the separation of the milk solids during extended storage. The cream is sterilised in a continuous flow by the direct application of high-pressure steam, after being preheated under pressure. The sterilising temperatures are between 260° and 280° F. and the time taken for sterilisation to be completed is approximately four minutes. The cream passes to a two-stage homogeniser, the pressure in the first stage being below 2,000 lb. per square inch and below 500 lb. per square inch in the second stage, the temperature of homogenisation being below 150° F. Care is taken with this process to ensure that the cream does not become too viscous. The product passes into cooling coils and finally into sterilised holding tanks, which feed the bottle-filling machine.

Bottling and capping are carried out in a separate room in which ultra-violet ray lamps emit sterilising radiations which destroy any bacteria or moulds likely to be present. The operatives wear sterilised overalls, gloves and masks and are subjected to regular medical examinations, particularly as regards the presence of respiratory diseases. Both bottles and caps

are sterilised with steam at 275° F. and the bottle conveyor is protected by a bank of bactericidal lamps. The bottles are filled and capped, and sterile conditions are maintained by washing and sterilising the entire room. The air of the room is washed and filtered and dust is precipitated and the desired temperature and humidity are maintained. Bactericidal lamps in the air ducts provide further precautions against contamination. The filled bottles are removed to the cold room on an air-cooled conveyor.

From each batch completed, a few bottles and their contents are incubated at 100° F. as a test of sterility, and others are subjected to a simulated churning action in order to test the stability of the finished article.

ARTIFICIAL CREAM

The advent of the Public Health (Preservatives, etc., in Food) Regulations, 1927, has been the cause of a great increase in the quantity of artificial cream manufactured and sold. In addition, the ban on the employment or sale of fresh cream during the war has also caused a rapid increase in the amount used. Particularly is this the case among confectioners, many of whom use this article as a filling for cream cakes and pastries, because of the losses likely to be sustained from the use of natural cream, which may quickly sour. Artificial cream is also useful on ships, or where it is necessary to cater for a variable market.

A varying nomenclature has been used to describe this article. It has been known as "Reconstituted Cream," but this is a most inaccurate description, as the article has never been cream. "Synthetic Cream" is a still more unfortunate caption, having been used to denote an article manufactured from fats derived from sources other than milk.

Artificial cream is manufactured in the home by means of small, hand-operated emulsifying machines, working upon the viscoliser principle. As already indicated, it is also manufactured upon a commercial basis. The ingredients used in its manufacture are unsalted butter, dried skim-milk powder, and water. If desired, liquid milk may be used in place of the dried-milk powder. Under the terms of the Dried Egg (Control of Use) Order, 1945, this substance may be used under licence for the production of artificial or synthetic cream. The Schedule to the licence states:

(a) Any dried egg used must be mixed with water, within one hour of mixing heated to a temperature of 170° F. at which it must be held for not less than 15 minutes.

(b) After this heat treatment not more than one hour must elapse before it is mixed with the other ingredients and the whole mix heated to a temperature of not less than 165° F. at which it must be retained for not less than 30 minutes.

(c) The synthetic cream must be cooled within half an hour to not more than 40° F. and retained at this temperature until despatched from the manufacturer's premises.

When prepared commercially, the necessary quantity of unsalted butter is mixed with water in a metal cylinder, following which the container is placed upon a hot-plate until the contents boil. The metal cylinder is then removed and placed below a motor-driven agitator, which revolves at a high speed within the mixture. After the motor has been started, the requisite quantity of dried-milk powder is added and the agitation continued for approximately five minutes. The product is next passed over a cooler, and is finally viscolised or homogenised to ensure a permanent and complete emulsion.

There have been several outbreaks of paratyphoid B. spread by artificial cream during the War, while cream-filled bakery foods are specially liable to staphylococci infection.

Following the widespread use of artificial cream, several attempts were made to introduce legislation controlling its sale and manufacture. In 1928, the Reconstituted and Synthetic Cream Bill was drafted, this being followed in 1929 by the Reconstituted Cream Bill, both of which attempts proved abortive. Later in 1929, the Artificial Cream Act became law. This has now been superseded by Sections 27, 28, and 29 of the Food and Drugs Act, 1938, set out below.

Food and Drugs Act, 1938

Definition: "Artificial cream" means an article of food which, though not cream, resembles cream and contains no ingredient which is not derived from milk except water or any substance which may lawfully be contained in an article sold as cream, being some substance not injurious to health which in the case of cream may be required for its production or preparation as an article of commerce in a state fit for carriage or consumption and which has not been added fraudently to increase bulk, weight or measure or conceal inferior quality.

Regulation of Sale.—Section 27. (1) No person shall sell, or offer or expose for sale, for human consumption under a description or designation including the word "cream" any substance purporting to be cream or artificial cream, unless—

(*a*) the substance is cream; or

(*b*) where the substance is artificial cream, the word "cream" is immediately preceded by the word "artificial."

(2) No person shall use any vessel for conveying artificial cream intended for sale for human consumption, or for containing artificial cream at any time when it is exposed for sale, unless the words "artificial cream" are printed in large and legible letters of uniform size and conspicuously visible either on the vessel itself, or on a label securely attached thereto.

(3) A person who contravenes any of the provisions of this Section shall be guilty of an offence.

Registration of Premises.—Section 28. (1) Artificial cream shall not be manufactured, sold, or exposed or kept for sale for human consumption except on premises registered by a Food and Drugs Authority:

Provided that registration under this Section shall not be required in respect of—

(*a*) the manufacture of artificial cream by any person solely for his domestic purposes; or

(*b*) the manufacture of artificial cream on any premises for use in the preparation on those premises of some other food; or

(*c*) the sale, exposure or keeping for sale of artificial cream on any premises where it is supplied only in the properly closed and unopened vessels in which it is delivered to those premises.

(2) A person who uses any unregistered premises shall be guilty of an offence and the court may order that any machine found on the premises which is suitable for use in the manufacture of artificial cream shall be forfeited.

(3) A Food and Drugs Authority shall, on the application of the occupier of, or of a person proposing to occupy, any premises, register those premises for the purposes of this Section.

(4) Upon any change in the occupation of premises registered under this Section, the incoming occupier shall, if he intends to use them for the purpose for which they are registered, forthwith give notice of the change to the Authority. who shall thereupon make any necessary alteration in their register. Provides penalty for non-compliance.

(5) Where a substance having the composition of cream or artificial cream

is sold or exposed or kept for sale on premises registered under this Section it shall be presumed to be artificial cream, unless the contrary is proved.

Application of Certain Provisions relating to Cream.—Section 29. Such of the provisions of this Part of this Act and of any Milk and Dairies Regulations as relate to cream, other than provisions relating to the registration of dairymen and dairies, shall, unless, in the case of regulations, the regulations otherwise provide, apply in relation to artificial cream.

The Sections of the Food and Drugs Act, 1938, relating to the adulteration and taking of samples which have already been outlined in Chapters I and II also apply to artificial cream.

CHAPTER III

BUTTER AND MARGARINE

BUTTER

Introductory

BUTTER is one of the staple articles of food in this country, and although the consumption of this article has fallen dangerously low during and since the War, as it did during the War of 1914–18, there is no doubt that when conditions become normal the consumption of this foodstuff will rise once more to a marked degree. In addition to the small quantities of farm-house or fresh butter produced in the agricultural areas of Great Britain, large quantities are manufactured in creameries and butter factories both in this country and in the Irish Free State, while further enormous supplies are imported annually from our Colonies, from Denmark, and from other countries. Indeed, in the United Kingdom, butter-making is now almost entirely a creamery industry, with the result that a more uniform product is produced. The great increase in imported supplies before the War raised the consumption of butter to a high level, the price of such supplies being quite comparable to that of good-quality margarine. In this connection, it is also interesting to note that the availability of butter at such reasonable prices was followed by a pronounced drop in the sales of certain of the cheaper varieties of jam. The annual consumption of butter in the United Kingdom prior to the War was approximately 15½ lb. per head, a total which was far below that of many other countries.

Since the advent of the Milk Marketing Scheme, butter-making has become more and more centralised in creameries and butter factories, although an unsatisfied demand still exists for the farm-house or fresh product. There can be little doubt that many farmers abandoned their butter-making activities before the War in favour of milk-selling, while it is probable that so long as milk prices remain at their present level, most farmers will never revert to their original practice of butter-making, as it would be a less profitable proposition. Against this is the freedom from Milk Board control which the farmer experiences, while there is the additional advantage that the separated milk is a valuable addition to the dietary of pigs and calves. In the past, the quality of farm-house butter has not been entirely reliable, and for this reason much educational work has been carried out amongst farmers to ensure that any butter which they do produce is uniform in quality.

Composition and Appearance

The composition of butter varies slightly according to the principles and practice of manufacture, but the average composition may be given as follows:

	Per cent.
Butter-fat	82·5
Casein	1·5
Lactose	2·0
Salts	2·0
Water	12·0
	100·0

Butter-fat contains butyric, caproic, caprylic, capric, myristic, palmitic, stearic, and oleic acids. The first four are soluble in water and are known as *soluble fatty acids;* the latter four are insoluble and are termed *insoluble fatty acids.* Butter-fat may also contain small quantities of lauric, arachidic, and dioxystearic acids.

Dr. J. Bell has published the following approximate average analysis of a sample of butter-fat:

	Per cent.
Butyric Acid	6·1
Caproic, Caprylic, and Capric Acids . . .	2·1
Myristic, Palmitic, and Stearic Acids . .	49·4
Oleic Acid	36·1
Glycerol	12·5

The percentage of soluble volatile acids in butter-fat serves to distinguish it from other animal or vegetable fats.

Butter varies in *colour* from white to deep yellow, and is of a more or less granular character. The natural colouring matter is known as *carotene*, but in practice there is no method of distinguishing between natural and added colouring matters without resorting to chemical tests. Winter-produced butter (in its natural state), both in this and in European countries, is usually pale in colour, artificial colouring matter being often added to improve the appearance. Such an addition is undesirable, since it deceives the buyer as to the nutritive value of the product. The colour fades on prolonged exposure to light. No preservatives may be added to butter to improve its keeping quality, but the use of common salt is permitted.

Butter possesses a characteristic *flavour* which, in this article alone of all the fatty foods, is produced naturally. The depth of flavour can be controlled by the acidity to which the cream is ripened previous to setting and churning. Four types of butter are recognised as standard, and these are set out in Table 9 below.

TABLE 9

Flavour	Cream Acidity per cent.	Diacetyl Parts per million
Flavourless .	0·10 to 0·15	Nil to 0·2
Mild . . .	0·15 to 0·20	0·5 to 1·0
Medium . .	0·20 to 0·30	1·0 to 2·5
Full Flavour .	0·30 and over.	3·0 to 4·5

Butter usually improves in flavour up to a period of forty-eight hours after production.

The keeping quality of butter depends upon the quantity of casein which it contains, while it is also influenced by chemical and bacteriological deterioration. Butter manufactured from sour milk or cream will possess a high casein content and the keeping quality will be reduced. Butter may become rancid on keeping, especially if the butter-milk has not been properly eliminated during manufacture.

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Chemical oxidation of the fat is extremely important and the change occurs most rapidly under acid conditions, being accelerated by high temperatures and when traces of copper are present. Bacteriological rancidity is due to the lipolytic decomposition of the fat content. The change is rarely related to the number of organisms present, but depends upon the activity of certain species, the most deleterious being lipolytic bacteria, organisms of the coliform group, and certain moulds and yeasts (see page 151). Bacterial growth is readily suppressed by salting, but highly-salted butter is not liked by the average consumer. Generally speaking, it may be stated that it is impossible to combine full flavour with long keeping quality in cold storage. The solution to the desire for long keeping quality appears to rest in the production of dehydrated butter oil, which can be made up into butter as required (see page 167).

All butter possesses an aroma peculiarly its own, some types being richer in this quality than others. This aroma, which may be simulated in butter substitutes by the artificial addition of flavour, owes its origin to a product formed by the bacterial cultures used as "starters" or artificial ripeners for the cream, the responsible organism being the *Streptococcus cremoris*. The substance actually responsible for the aroma is known as *diacetyl*, which is formed following fermentation by certain types of lactic acid organisms. This can be produced artificially, and has often been added to low-grade butter to improve the aroma to any desired degree. As this substance exerts an oxidising effect upon the fats contained in the butter, its addition in too large a quantity will cause the butter to become rancid. The less diacetyl the butter contains, the longer will it keep. This chemical probably exerts a detrimental effect upon the vitamin A content of the butter, thus appreciably reducing its nutritive value.

Butter has often been found to be adulterated by the addition or substitution of foreign fats, such as coconut oil or margarine, and by the incorporation of excessive quantities of salt, water, or preservatives. As previously stated, the addition of preservatives to butter is illegal, while the quantity of water which it may contain is limited to 16 per cent. of the whole. In America, in addition to a limit of 16 per cent. of moisture, butter must also contain not less than 80 per cent. of butter-fat. Casein and starch have also been added to butter, the former as a scientific adulterant, the latter presumably as a drier.

Food Value

Butter is one of the most palatable milk products. It is easily assimilable, and for this reason it is an unfortunate fact that its food value and economic importance have hitherto been insufficiently recognised. In view of the propaganda which was carried on, urging the public to recognise and utilise the food value of milk, it is rather peculiar that the more extensive use of butter did not receive stronger emphasis. Any diet prescribed to promote the proper growth of our child population or the maintenance of health in the adult should include a butter ration at least double the pre-war average consumption.

Following the application of scientific principles, together with the improved facilities for transport over enormous distances, butter to-day is more readily obtainable than ever before. It is one of the most concentrated of all dairy foods, this being obvious when it is remembered that 1 lb. of

butter contains as much butter-fat as 25 to 30 lb. of fresh milk.   It has a calorific value of approximately 3,300 calories per pound.

There is complete unanimity amongst all persons conversant with the vital subject of nutrition that milk products, including butter, must of necessity occupy a prominent place in the dietary both of children and of adults.   The consumption of butter in this country was increasing daily up to the outbreak of War, but it still lagged far behind our economic capacity.   The average annual consumption of butter in 1939 was 15½ lb. per head of population, i.e. just under 5 ozs. weekly for each individual.   This is equivalent to 3 to 4 gallons of milk weekly for every family of four persons.   The inadequacy of these figures will be seen when it is stated that the consumption of butter in Australia was 30 lb., and in New Zealand 37 lb. per head annually.

Butter forms one of the most easily and completely digestible fats and is a recognised source of vitamins A and D.   Summer butter contains more vitamin A and B carotene than winter butter, while during storage at 10° F. or below, the loss of vitamins is very small.   Sir George Newman has stated that, although starvation is rare in this country, many individuals suffer because they deprive the body of certain foods which the tissues require.   Evidence of this is shown in the number of cases of mal- or sub-nutrition, primary anæmia, rickets, and dental caries which are still discovered annually at School and Maternity and Child Welfare Centres.   Sir George has also stated that vitamins A and D, protein of high biological value, calcium, and iron are most often missing from average diets.   These deficiences can be readily supplied by an increased butter consumption.

In the diet of poorer families, margarine is used in place of animal and fish fats (butter and cod-liver oil) containing vitamins A and D on the grounds of economy, although there is very little difference between the prices of high-grade margarine and butter.   In *A Survey of Present Knowledge of Vitamins,* published in 1932 under the auspices of the British Medical Research Council, it is stated that pasture-fed butter-fat contains approximately twice as great a quantity of vitamins A, D, and E as does dry-fed butter-fat, while margarine, whether of animal or vegetable origin, is practically devoid of vitamins, except where the product has been specially enriched by a vitamin-adding process.

Dr. H. C. Corrie Mann has reported the following results of experiments in feeding, with particular relation to the addition of butter and margarine to ordinary basic diet.   Sixty-one boys who received only the basic diet gained an average of 3·85 lb. per boy and grew an average of 1·84 inches per boy during twelve months.   Twenty-six boys received 1¾ ozs. of New Zealand butter—387 calories daily—in addition to the basic diet.   They gained an average of 6·30 lb. per boy and grew an average of 2·22 inches during the twelve months (in order to obtain the type of butter which would not alter in composition during the period of the experiment owing to the different seasons of the year, a guaranteed New Zealand butter was used).   Sixteen boys received 1¾ ozs. of vegetable margarine—379 calories—as an additional daily ration.   They gained an average of 5·21 lb. per boy and showed an average growth of 1·84 inches during the period of the experiment.   The vegetable margarine contained no butter-fat and was reported to be deficient in vitamin A.

Professor J. A. Nixon, in an address given at the Annual Conference of the Central Council for Health Education on November 22nd, 1934, stated:

"Fats not only give a high calorie yield in compact form, but they are the chief source of vitamins A and D. They yield more than twice as many calories per gram as do proteins or carbohydrates. But they must be chosen judiciously. Butter and cream are the most palatable and assimilable forms of fat. Besides their calorie yield and their satiety value, we look to fats for supply or sufficiency of vitamins A and D. But from the public health aspect it is essential to realise that all fats do not yield these two vitamins in sufficient, or, it may be, any appreciable quantity. Lard, because of the method of preparation, contains practically none. Margarine may be marketed of such composition, that the vitamin content is negligible."

Evidence is thus available to show that butter is one of the most economical and most valuable of foods, and deserves a much more prominent place in the national diet than it has been accorded.

Butter and Disease

Very few outbreaks of disease have been traced to the consumption of butter. An outbreak of *typhoid fever* was reported from the United States of America in 1917, seven cases being notified. Butter produced on a farm, from unpasteurised cream, on which a person was employed who was suffering from the disease, was the cause of the outbreak. In another instance, ten cases of this disease were reported following the consumption of butter also made from unpasteurised cream. Another outbreak of typhoid fever was traced to a "carrier" who made and sold butter to a retail shop, while in another epidemic, the affected persons had all partaken of butter or butter-milk obtained from a farm and manufactured from infected raw cream and where a case of typhoid fever existed on the premises. The causative organisms of *tuberculosis* have been isolated from butter bought in the normal way and it has been proved in this respect that price is no guarantee of safety. An outbreak of *food poisoning* due to butter which contained *Staphylococcus aureus* has been reported, 70 persons being affected of whom two died. An outbreak of *diphtheria* is reported which was traced to a "carrier" of the disease who was working on a farm at which the butter concerned was produced.

Theory of Butter Manufacture

Various theories have been evolved to account for the action of churning in butter-making. Fleischmann has stated that the fat globules in the cream reach a superfused condition, and that the action of churning merely brings about a process of solidification. Storch, on the other hand, considers that the fat globules possess a solid, retaining membrane which acts as a skin. He holds the view that the action of churning gradually destroys this membrane, and that, as the globules are driven together during the churning process, they tend to coalesce, nuclei being formed which increase as churning progresses. His theory is that the fluid friction exerted upon the surfaces of these nuclei decreases as they grow in size, as compared with the force of attraction between the nuclei themselves. Eventually the two forces balance, the butter-fat nuclei coalesce and form a "clot" as the butter "comes."

The first action of churning causes the cream to thicken, and, as the size of the nuclei increases, these move more easily through the watery serum

or butter-milk, an almost complete separation becoming possible. The subsequent "working" of the butter grains renders the product practically homogeneous, any liquid which the mass contains forming tiny globules which cannot be removed by external pressure. The percentage of water in the butter can be controlled by the regulation of the working process.

The control of the butter-making process is important. The fat which remains in the butter-milk should not exceed 1 per cent., although, with sweet cream, 2 per cent. is regarded as satisfactory. As regards butter production, an economic problem of considerable importance is the comparatively high loss of fat during manufacture. Higher percentages should be considered unsatisfactory and are due to:

(1) Cream of too thick a consistency.
(2) Cream of too variable a consistency and age.
(3) Cream possessing an excessive temperature.
(4) Too rapid churning.

The cream to be churned should contain from 25 to 35 per cent. of butter-fat if satisfactory results are to be expected. If richer creams are used, the butter-milk will possess a high fat content, when considerable wastage will occur.

Factors influencing Manufacture

Certain important factors influence the manufacture of butter. These are:

(1) Breed of Cow.
(2) Artificial Ripening Cultures.
(3) Type of Cream.

(1) Breed of Cow.—The quantity of milk required to produce a given quantity of butter varies considerably in accordance with the breed and individuality of the cows from which the milk has been obtained, this factor being of no little importance. Generally speaking, it may be stated that $2\frac{1}{2}$ to 3 gallons of milk, i.e. 25 to 30 lb., will be required to produce 1 lb. of butter. The variations in butter-making capacity of the milk of different breeds of dairy cattle may be stated as follows:[1]

Red Poll
Ayrshire
Shorthorn   } 1 lb. of butter from 24 to 32 lb. of milk.
Lincoln Red
Friesian

South Devon
Kerry   } 1 lb. of butter from 20 to 27 lb. of milk.
Dexter
Welsh

Jersey   } 1 lb. of butter from 16 to 24 lb. of milk.
Guernsey

It will be observed that the Channel Islands' breeds yield milk containing the highest percentage of butter-fat, while their milk possesses the additional advantage that the fat globules contained are larger than those found in the milk yielded by other breeds. The cream is thus more readily separated from the milk.

[1] Reproduced by permission of the Controller of H.M. Stationery Office from Bulletin No. 57 of the Ministry of Agriculture and Fisheries—*Butter, Cream Cheese, and Scalded Cream* (1933).

(2) Artificial Ripening Cultures.—The use of some form of artificial ripening culture or "starter" for ripening cream in butter-making is not essential, although the practice is now fairly general and possesses many decided advantages. If the cream is allowed to ripen naturally, a danger exists that the butter will possess a poor keeping quality, due to the action of certain bacteria and moulds which may have gained access to the milk during production or to the cream during the ripening process. When a "starter" is used, the growth of those bacteria essential to the ripening process may be efficiently controlled.

The advantages to be derived from ripening cream, either naturally or artificially, are:

(a) Cream churns more readily than does material separated immediately from fresh milk.

(b) The resultant product possesses a more satisfactory flavour.

Like many other practical discoveries, the method of souring cream for butter-making owes its origin to chance. Many years ago it was the custom among small butter-makers to allow the cream to stand for several days in order to avoid the labour of churning small quantities of cream daily. The different batches of cream were mixed together and, on standing, the whole became sour, due chiefly to the action of the lactic-acid group of organisms. In those days, butter prepared from the soured cream was usually bad, but, by means of experiment, the more objectionable defects of the method were remedied. It was further found that butter manufactured from ripened cream possessed a particularly pleasing aroma, which was never present in butter made from sweet cream.

As experiments progressed, it was discovered that desirable properties could be imparted to fresh cream by the addition of a small quantity of soured milk or cream which was known to be in a satisfactory condition. These additions became known as "starters," and it was ascertained that, by their use, butter of uniform quality could be produced as and when desired. When the part played by bacteria in the souring of cream was established, it was in turn found that certain bacteria were harmful, while others were beneficial to the process. Thus it came about that pure artificial ripening cultures were devised, allowing the butter-maker to control the ripening of his cream in a scientific manner.

When dealing with pasteurised cream, or when large quantities of cream are concerned, it is essential that a *pure* artificial ripening culture or "starter" should be used. Many large creameries manufacture their own types of ripening cultures, but these may be procured from most Agricultural Colleges and from County Farm Institutes upon payment of a small fee.

Artificial ripening cultures are of two types:

(a) Natural "Starters."

(b) Pure Culture "Starters."

(a) *Natural "Starters."*—These are generally obtained from butter-milk, from whey, or from milk, obtained from a healthy cow, which has been allowed to sour. The latter liquid is collected in a clean condition and is stored until clotted, when the fat layer is skimmed off and discarded. The remainder is mixed with the cream in a similar manner to the butter-milk or whey. Such "starters" may be tested by appearance, taste, or smell. The taste and smell should be agreeable, while there should be no whey showing upon the surface or any digestion of the curd.

(b) *Pure Culture "Starters."*—Such "starters," composed of various desirable types of true lactic-acid organisms, are sold either in liquid or in powder form.

They may be purchased in bottles, each of which contains sufficient to sour the cream for one process of butter-making. They are not used as purchased, but are propagated in freshly separated milk The milk is usually pasteurised and cooled before being inoculated with the culture. The entire contents of the bottle of "starter" is added to the milk, which is then allowed to stand until coagulation takes place. The surface layer is discarded, after which ½ pint of the milk is added to 1 gallon of fresh milk, which is thereafter treated in a similar manner. Two or three sub-cultures, carried out in this manner, bring the "starter" into vigorous activity. In creameries, where expert assistance is available, cultures of lactic-acid organisms can be propagated continuously without deterioration ; but if any defect, such as bitterness or taint, develops, the "starter" should be discarded and fresh cultures purchased.

The natural ripening of cream, due to the multiplication of the lactic-acid organisms, does not result in the production of a butter uniform in quality at all times, whereas the use of artificial ripening cultures, by which the degree of acid fermentation may be controlled, ensures a product uniform in quality on every occasion.

(3) **Type of Cream.**— *It is essential that all cream used in the manufacture of butter should be efficiently pasteurised prior to use.* For this purpose the cream should be heated to a temperature of 150° to 165° F., and then *immediately* cooled to a temperature of between 60° and 70° F., according to season. The ripening of pasteurised cream can be scientifically controlled by means of artificial ripening cultures. This is a decided advantage as it ensures the production of a butter of uniform quality.

Manufacturing Premises

The premises in which butter is manufactured are of particular importance, their design and construction requiring considerable care and forethought. The type and size of building required naturally vary according to circumstances. In considering the essential points to be dealt with in the planning and construction of premises, it is convenient to subdivide such premises into two broad types, as follows:

(1) Farm-house Dairies.
(2) Creamery Premises.

(1) **Farm-house Dairies.**—Manufacturing premises at the farm will obviously be considerably smaller than those required for butter factories. The farm-house dairy should be divided into three separate rooms:

(a) Cream-ripening Room.
(b) Dairy.
(c) Washing Room.

It is essential that the dairy building should be a separate structure, situated apart from other farm buildings. The *size* of the building will depend upon the quantity of butter which is likely to be produced. A large turnover demands appropriate floor area, but it is advisable in all cases to have the *maximum* degree of space available, in order to give adequate working capacity, not only for the sake of convenience, but also as an aid to cleanliness.

The *aspect* should be such that all main windows face in a northerly direction, so that adequate light may be provided without the admission of strong, direct sunlight. All *windows* through which sunlight is likely to obtain entrance should be glazed with tinted glass to prevent excessive heating of the rooms.

The building should be constructed of brick, stone, or concrete blocks. The *roof* should consist of such material as will adequately insulate the building and so prevent excessive heat in summer. Tiles, slates, or corrugated asbestos sheeting are entirely satisfactory for this purpose.

As a large quantity of water will be required for a variety of purposes, it is essential that an *adequate, pure-water* supply should be provided. Contamination of the water supply used for washing the butter will prevent the production of butter of good flavour and keeping quality. *Taps* should be fixed at all essential points, and a *storage cistern* provided for any boiler used for steam-raising purposes.

With respect to the individual rooms in the building, the following details are of importance:

(a) *Cream-ripening Room.*—It is essential that this room should be entirely separate from the remainder of the building. The cream may have to ripen here for several days, during which period it is open to bacterial and atmospheric contamination. For this reason the room should be used for no other purpose than that for which it was definitely intended. Arrangements must be made to control the *room temperature* at all times during the ripening process, while some form of heating apparatus, preferably of the low-pressure type, should be installed. The *floors* should be constructed of concrete or red tiles draining to a trapped gully outside the building, and should be washed down daily. The *walls* should be faced internally with cement, or preferably with glazed tiles, from floor to ceiling.

Adequate *natural and artificial lighting* is essential. The *ceiling* should be flat, unless it is necessary to depend upon roof lighting as a means of natural illumination. In such circumstances the roof should be cased in with match-boarding or asbestos sheeting. This lining should be painted. There should be no crevices or corners in which filth or dust can accumulate, all angles being rounded. Suitable benches, constructed of hard, impervious, and easily cleansed materials, are necessary upon which to stand the cream-ripening pans. A *hatch* situated in the intervening wall should be the sole, direct means of communication with the adjoining dairy.

(b) *Dairy.*—This room must, of necessity, be considerably larger than the cream-ripening premises, as it is here that the processes of cream separation and pasteurisation, together with the churning, working, making-up, and storage of the butter, will take place.

The internal construction of the dairy should be similar to that of the cream-ripening room. The dairy should contain the cream separator, a batch pasteuriser, a cooler, which may be used for cooling both the milk after production and the cream after pasteurisation, churns, and a butter worker. A box refrigerator or an automatic refrigerator should be provided for hardening the butter after manufacture, and for storage purposes until the product is sold.

Provision must also be made for the cleanly storage of salt and other materials and for the utensils after sterilisation until required for use. It is not advisable that such utensils should be stored in the washing room, as they may then be open to contamination.

(c) *Washing Room.*—The utensils should always be washed and sterilised in a separate room, the internal construction of which should be similar to that of the two rooms already described, with the exception of the red-tiled floor and glazed tiled walls, which are not essential. Hot- and cold-water

tanks and a steam chest of suitable size should be provided. *Steam* is essential, as this provides the most efficient means of sterilising the various articles used. The cooler and the separator must receive special attention in this respect, as such apparatus, if not properly cleansed and sterilised after each operation, will adversely affect the flavour and keeping quality of the butter.

The steam boiler may, if desired, be fitted inside the room, although external installation is preferable, in order to prevent any dust or dirt from the fuel gaining access to the room. Sufficient working space must be provided, and the only communication between the dairy and the washing room should be by means of a hatch situated in the intervening wall.

(2) **Creamery Premises.**—Butter factories or creameries are planned and constructed upon similar lines to those of small farm dairies, except that they are considerably larger and on a more ambitious scale. The premises are so planned that the milk passes in at one end of the creamery, to leave at the other in the form of butter, the process being arranged to operate in consecutive stages. A proper understanding of creamery premises may be more readily arrived at if the processes which take place are briefly described.

The milk or cream is delivered at the creamery from a varying number of farms by road or rail, in churns and in tank wagons. It is usually weighed immediately upon arrival, samples being taken from each supply at frequent intervals. These are analysed for butter-fat content, payment being made according to results, while samples are also taken for either resazurin or methylene-blue tests. The milk is then pumped or tipped into receiving tanks, from which it is drawn to a preheater, which raises the temperature of the milk to between 80° and 90° F. This facilitates the separation of the cream from the milk. The heated milk then passes to mechanical separators. The skimmed milk from these separators is pumped up into receiving tanks situated upon an upper floor, whence it can be discharged by gravity into the farmers' churns and returned to them for further use.

The cream from the separators passes to the pasteuriser, where it is processed either by the "flash" or officially recognised methods and is finally cooled after treatment. When the butter is manufactured from ripened cream, the cooled cream passes to the ripening room, where it is stored in vats and allowed to ripen, this process being accelerated by the addition of ripening cultures. If sweet-cream butter is manufactured, the cream, after pasteurisation, is pumped to mixing vats situated upon an upper floor. These vats are surrounded with brine jackets, the cream being stored overnight at a temperature of 40° F. Both the ripening vats and mixing tanks are fitted with paddles, which may be used to agitate the cream gently during storage.

When the cream is ripe or when overnight storage has been completed, the cream is fed to combined churns and butter workers, where it is churned, washed, and worked to the desired consistency. The butter-milk from the churns is run off into storage tanks situated on an upper floor, where it can, as in the case of skimmed milk, be discharged by gravity into the farmers' cans or receptacles. The worked butter may then pass to a weighing machine, where it is weighed into 56-lb. boxes, or it may be prepared by machine into ½-lb. or 1-lb. blocks, these being afterwards wrapped and packed ready for dispatch.

It will be readily understood that the installation of such plant necessitates considerable space, and that ingenuity in construction is required in order that the process shall be continuous. The essentials of satisfactory creamery premises may be briefly stated as follows:

(i) Sanitary construction, with ease of cleansing.
(ii) Adequate, *pure*-water supply.
(iii) Sufficient natural and artificial lighting.
(iv) Provision of steam for pasteurisation and sterilisation.
(v) Suitable storage for the finished article and for raw materials.

Sources of Contamination

Cleanliness in the manufacture of butter is of the utmost importance, not only because the raw materials of which it is composed are of a perishable nature, while the use of preservatives is prohibited, but also because the product cannot be sterilised after manufacture unless some dehydration process is employed. Butter with sufficient keeping qualities to satisfy the requirements of the trade and the consumer must be provided, and such preservation can only be controlled by the bacteriologist. Butter may be contaminated by impurities from the following sources:

(a) Raw Materials.
(b) Salt.
(c) Packing Materials.
(d) Water Supply.
(e) Air of Premises.
(f) Utensils.
(g) Premises and Plant.
(h) Personnel.

(a) *Raw Materials.*—When it is remembered that the principal raw material used in the manufacture of butter is milk, or more correctly the cream separated from milk, there will be no need to emphasise the danger of using milk which is of poor quality, which possesses a high bacterial content, or which contains pathogenic organisms. It can be categorically stated that the quality of the finished product will only equal the quality of milk from which it has been manufactured. In spite of this fact, it has long been held that poor-quality milk which could not otherwise be utilised was suitable for manufacturing purposes. Indeed, under the National Milk Testing Scheme, it was decided, had conditions allowed, that Category B milk should be salvaged for manufacture into milk products. This is a dangerous fallacy, as there can be no doubt that inferior milk will yield an inferior article. One batch of milk of doubtful quality, when mixed with good milk at the creamery, will endanger the remainder of the mixture, however clean or pure this may originally have been, and will be sufficient to ruin the entire batch of butter manufactured from the mixed product. It is therefore essential that all deliveries of milk should be suitably tested and examined. Such an examination would show, not only the condition of the milk upon arrival at the premises, but would also yield an indication of the degree of cleanliness under which the milk had been produced and handled. Pasteurisation will do much to remove or reduce a high bacterial content, but such milk cannot usually be recommended, as no processing will render dirty milk clean. Milk as received should be filtered to remove any extraneous

matter before any processing is undertaken, by means of one of the many types of cloth filters available. It is also advisable that milk should be purchased upon a basis of a bacterial count as well as on a quality basis.

(b) *Salt*.—This is an important ingredient in the manufacture of butter, and, although it is generally regarded as a sterile preservative material, it is not always free from impurity. If it is packed or transported in unsuitable containers, or stored in an unsatisfactory manner, it can and does become contaminated. This material must be used as purchased, since any cleansing process would render it unsuitable for use. A guarantee of purity is generally included in the appropriate specifications, but is also necessary to ensure that suitable storage is provided.

(c) *Packing Materials*.—These materials, which include labels and wrappers, cannot be washed although they may be sterilised, if desired, and may, if of poor quality, or if stored under insanitary conditions, be a fertile source of contamination, particularly as wrappers come into direct-contact with the product. Only the highest quality packing materials should be used, and these should be stored until required in a clean, dry place. Wood or cardboard, which is often used for the manufacture of containers, forms an excellent breeding-ground for bacteria if these precautions do not receive attention.

(d) *Water Supply*.—This may also be a source of gross contamination. Even when the source of supply, whether from wells or from the mains, is satisfactory, contamination may occur in storage tanks or in the service pipes. The storage tanks should receive periodical cleansing, during which they should be emptied, any sediment removed, and the tanks suitably treated with disinfectant. All traces of disinfectant may and should be removed by washing out the tank with fresh water.

(e) *Air of Premises*.—The air of the premises is frequently a source of impurities, the prevention of this type of contamination presenting serious difficulties. The atmosphere contains large numbers of micro-organisms which may obtain entrance to the product and develop there. Many factories rely upon the quality of the natural air, which, in many cases, is purer than the air inside the factory. On the other hand, a considerable degree of impurity may be introduced into the processing rooms during foggy weather, and may contaminate the exposed foodstuff. Air-conditioning plants will solve the difficulty, although such plants, sufficiently large to deal with all the air entering the factory, would of necessity be expensive. When these are employed, the air is first washed by water sprays as it passes over baffle plates, this affording an appreciable degree of purification. The purified air is cooled in summer or heated in winter as desired. The air intake should be situated well above the roof, as if this is not the case, dust and dirt settling on the roof surface will be drawn into the plant. Care should be taken to ensure that the water used for washing the air is maintained in a pure condition. Such water is usually circulated continuously, and for this reason the addition of 0·25 per cent. sodium hypochlorite is essential.

(f) *Utensils*.—All containers, small tools, brushes, and other utensils may form potent sources of contamination. These articles should be washed thoroughly after use and finally sterilised with steam. The efficient storage of such utensils is also of paramount importance. "Starter" containers should invariably be constructed of stainless steel or glass-enamelled metal.

Tinned copper utensils employed for this purpose may be a source of danger due to the exposure of the copper base, and a solution of copper in the "starter" will be the cause of many defects in the final product.

(g) *Premises and Plant.*—Accumulations on floors, walls, ceilings, and girders, etc., all form possible sources of contamination. Extreme cleanliness of the plant is essential. This is only possible by correct cleansing, which in turn is greatly assisted by correct construction. Contamination of the product may follow contact with various metal surfaces, and a periodical examination of all such surfaces is essential so that any which are worn may be dealt with. By the selection of suitable metals and cleansing methods, together with the use of high-grade detergents, the risk of any metallic contamination causing tallowy flavours or undesirable colour taints may be obviated. Metal surfaces for tables or benches are easily cleansed and are practically sterile. Wood should on no account be used for this purpose, as it is a permanent source of danger because of its porosity, and also because of the fact that it cannot be rendered sterile. If wooden equipment is employed, large numbers of bacteria may enter the butter and an inferior product will result..

(h) *Personnel.*—It is very necessary to guard against contamination of raw materials prior to use and also the contamination of butter after production, caused by infected or uncleanly employees. All employees applying for work should be medically examined before being allowed to commence duties, and regular supervision should also be undertaken as routine. Any family illness should be notified to the manager or supervisor, and steps taken accordingly. The hands of the employees are particularly important. These should be inspected at frequent intervals. Sufficient washing accommodation with hot and cold water, soap, clean towels, and nail brushes should be provided. The employees should also be provided with white overalls and head coverings. These should be changed weekly. It is particularly important that the materials of which such overalls are made should be light-coloured, as dirt is then rendered more easily visible. Dressing-rooms where workers may change from their ordinary clothing to the overalls should be provided wherever possible.

Method of Manufacture

Two types of butter are produced for public sale. These are:
- (1) Ripe-cream butter.
- (2) Sweet-cream butter.

The manufacturing methods used in the production of both types of butter are in all respects similar, variation only existing in one detail. In the manufacture of ripe-cream butter, the cream is allowed to ripen either naturally by the multiplication of the lactic-acid organisms which it may contain, or artificially by the addition of an artificial ripening culture or "starter." Sweet-cream butter, on the other hand, is manufactured from cream which is churned at very low temperatures without any natural or artificial ripening. The manufacture of this type of butter is concentrated in the United States of America and the Colonies, as under suitable conditions it can be stored for long periods. This method of manufacture is not altogether a matter of choice, but due to the system of collection in which farmers separate the cream and despatch it to the creameries with the result that high acidity develops which must be removed by neutralisation. The

cream is tested on receipt at the factory, a measured quantity being placed in a test-tube and mixed with a gelatine capsule containing an indicator solution and a quantity of alkaline solution sufficient to neutralise an acidity of 0·15 per cent. If it contains a higher percentage of acidity, the colour remains unchanged and the cream is placed in a lower grade. Butter which has been produced from ripened cream is generally regarded as being of the better quality when manufactured under standardised conditions, and is chiefly home-produced or imported from near-by countries, such as the Irish Free State and Denmark. Irish creameries pay for the butter-fat only, returning the separated milk to the farms, but Danish creameries pay for their cream on butter-fat value and on the result of a methylene-blue test. An increasing demand for sweet-cream butter is being evidenced, and in the case of this latter type, artificial colouring matter is usually absent. It is in great demand for use in the manufacture of reconstituted cream, and possesses a mild, almost insipid flavour which many consumers prefer. Taints are likely to develop owing to the absence of acid-forming "starter" organisms which inhibit the growth of those bacteria, etc., which produce undesirable flavours.

The manufacture of *sweet-cream butter* possesses the following disadvantages:

(a) The churning of fresh cream involves a greater loss of fat in the butter-milk and the process takes considerably longer than when ripened cream is used. This method is therefore only used where the increased price obtainable for the product compensates for the loss of fat.

(b) Sweet-cream butter is rather tasteless, and does not possess the characteristic flavour associated with butter manufactured from properly ripened cream.

German scientists have contributed many ideas on butter-making, particularly as regards the removal of excess acidity without the use of chemicals. A quantity of cream is mixed in a tank with an equal amount of pure water. This mixture is agitated for ten minutes, after which the temperature is raised to 100° F., and is then passed through a cream separator. The acidity is reduced by half in this manner and the washed cream, after separation, contains approximately 45 per cent. of butter-fat. An equal quantity of pasteurised separated milk is mixed with it in order to restore the solids-not-fat content lost during the washing process and to bring the cream to the desired consistency for ripening and churning. The cream now possesses a butter-fat content of between 24 and 28 per cent. Separated milk is then employed for standardisation and the liquid is ripened until ready for churning. It is stated that not more than 0·03 per cent. of fat is lost during the process.

Two continuous butter-making processes were developed in Germany during the war, and are reported by the British Intelligence Objectives Sub-Committee. These are:

(a) The Alfa Process.
(b) The Fritz Process.

(a) *The Alfa Process.*—This system is continuous and eliminates the use of a churn. Raw milk is preheated to a temperature of between 113° and 122° F. and then separated to give a cream of 25 to 30 per cent. fat content. This cream is pasteurised at 203° F. in a plate pasteuriser and then cooled to temperatures between 140° and 158° F. It then passes to a hermetically-sealed separator which produces a concentrated cream with a butter-fat content of approximately 78 per cent. The temperature of the cream issuing from the separator varies between 140° and 158° F. and this rich substance is pumped through a brine cooler which

consists of three cylinders each about 6 feet in length and 1 foot in diameter. Each cylinder contains a spiral coil of stainless steel which is surrounded by brine or water. The cream emerges from the bottom cylinder at a temperature of 68° F. and from the middle cylinder, in the form of a viscous butter at between 48° and 50° F. It is warmed in the top cylinder to render it more fluid, the butter issuing at a temperature of 57° F. The liquid butter flows into parchment-lined wooden boxes and at this stage appears similar to thick cream and has a clean, fresh flavour. The sealed boxes are placed in a cold store, the product solidifying with the appearance of normal butter with no visible signs of free moisture. The flavour improves with storage. The solidifying temperature is approximately 45° F. and the product has a fat content of 78 per cent. with 20 per cent. of water and 2 per cent. non-fatty solids. The moisture content can be controlled within wide limits and an 8 per cent. content can be achieved if desired. The plant has a capacity of 550 lb. of butter per hour and several commercial plants are in operation. The inventor, Professor Möhr, claims that this type of butter possesses a satisfactory keeping quality due to the uniform nature of the emulsion and to lack of contamination from washing water and air.

(b) *The Fritz Process.*—Quite a number of plants using the Fritz process are in operation in Germany. This method of manufacture was developed by Dr. Fritz in 1939 and differs considerably from the Alfa process. Cream containing 40 to 45 per cent. of butter-fat is pasteurised at 203° F. and then cooled to between 45° and 50° F. according to the desired firmness of butter required. This cream, after cooling, enters a large storage tank where a uniform temperature and fat content are maintained. It is pumped from this tank to a small central container at constant pressure and at an adjustable rate and travels to a small water-jacketed cylinder approximately 10 inches in length and 10 inches in diameter, surrounded with a jacket through which cold water is circulated. The cream strikes a baffle on entering the cylinder and a thin film forms on the inner surface, being maintained from the inflowing cream by four, straight horizontal blades rotating at 3,000 revolutions per minute about a horizontal axis. Butter granules form and the butter-milk is separated from the cream in a minute and a half. The contents are discharged from the cylinder into another vessel which contains two worms about 18 inches long and 6 inches in diameter which rotate at 40 revolutions per minute in opposite directions. The butter granules are conveyed up an incline and through a rectangular opening 2½ inches long, the butter-milk being pressed from the butter and discharged by gravity. The butter on emerging from the opening passes on to two further but shorter worms which force the butter through a perforated plate from which, on the further side, it is removed by rotating blades. The butter emerges in a convenient form for packing. Churning temperatures are in the neighbourhood of 44° to 50° F., according to season, and the temperature of the cold circulating water is approximately 39° to 41° F. The moisture content of the butter can be controlled as desired. At present, the moisture content is about 20 per cent., but this can be reduced to 11 per cent. This process was designed for handling sweet cream, and plants have been constructed which will produce up to 2 tons of butter per hour. The flavour and storage life of the butter are said to be similar to that of butter made by the "Alfa" method.

With both methods, a great saving in labour is possible, while the apparatus used is easily cleansed.

The process of butter manufacture may be divided into the following stages:

(1) Cream Separation.
(2) Pasteurisation of Cream.
(3) Cream Ripening.
(4) Churning.
(5) Washing and Salting.
(6) Working.
(7) Making-up.

(1) **Cream Separation.**—It is usual to separate cream from milk for the manufacture of butter, although butter may, if desired, be produced by churning whole-milk. This latter process is now seldom attempted, as production occupies considerably longer than is the case when cream is churned, while the results are not satisfactory, too large a percentage of cream being retained in the butter-milk. Cream can easily be separated from the remainder of the milk, if such milk is allowed to stand for a period, the butter-fat rising to the surface and being skimmed off as cream. A more satisfactory method is to separate the cream by means of one of the many types of mechanical separator now upon the market. The most popular types are those with capacities ranging from 660 to 1,100 gallons per hour, many of these being of the non-foam type. This is the method employed in butter factories, and need not be discussed further here, as the subject has already received attention on pages 84 to 89. In order that the best possible aroma should be obtained during ripening, cream should not possess too high a fat percentage so that the bacteria responsible for its production may find, in the milk sugar and citric acid, substances from which the flavouring principles originate and which impart the desired flavour and aroma. A percentage of 23 to 24 per cent. is usually sufficient.

[ALL TEMPERATURES ON FAHRENHEIT SCALE]
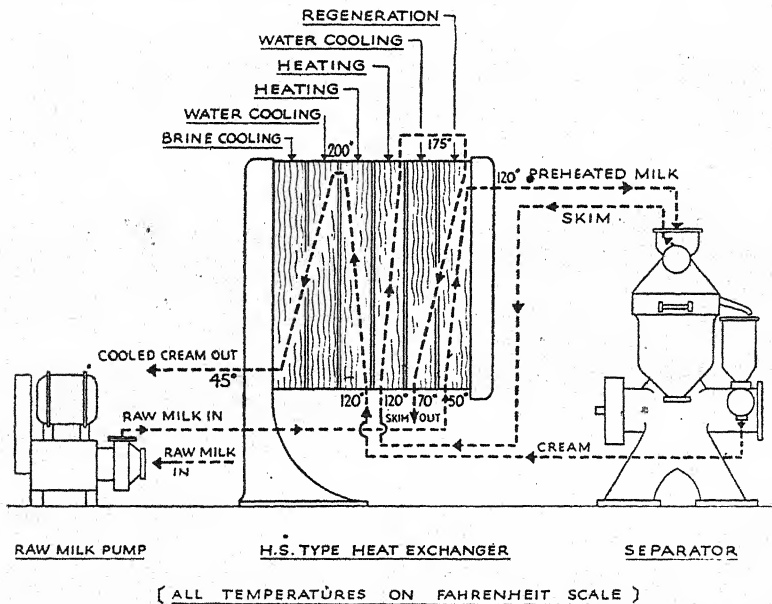
By courtesy of the Aluminium Plant & Vessel Co., Ltd.

FIG. 37—Cream Separator and Pasteuriser (Flow Diagram)

(2) **Pasteurisation of Cream.**—From a public health point of view, the pasteurisation of cream after separation is essential, whatever type of butter is produced. Milk as received at the creamery cannot be guaranteed free from pathogenic organisms, however low its total bacterial count may be. If pathogenic organisms are present in the milk prior to separation, they will be present in the butter unless the cream is pasteurised.

Apart from the public health aspect, the pasteurisation of cream after separation is an essential requirement from a commercial standpoint. The use of artificial ripening cultures with pasteurised cream allows the process

of ripening to be scientifically controlled, thus ensuring a more uniform product. In some cases, the milk is pasteurised prior to separation. The process of pasteurisation is generally carried out in a plant on the lines of that illustrated in Figs. 30, 31 or 32, the cream being heated to 155° to 165° F. or even higher, maintained at this temperature for thirty minutes, and then immediately cooled to 60° to 70° F., according to season. The hardness of butter depends to a great extent upon the rapid cooling of the cream after pasteurisation, followed by lengthy cooling before churning, while the butter granules should be cooled after churning is completed. For these purposes, adequate refrigeration is essential. Higher temperatures are often employed and result in the destruction of lipolytic enzymes as well as bacteria. Pasteurisation is sometimes carried out by a continuous-flow system at temperatures in the neighbourhood of 185° F. and the cream is then immediately cooled. A process for pasteurising cream under vacuum has already been mentioned on page 91. In Australia, a process termed "Vacreation" is employed, the cream being flash pasteurised at 200° F., followed by two stages of vacuum treatment. This process is claimed to improve the flavour of long-keeping butter to a considerable extent.

(3) **Cream Ripening.**—After pasteurisation has been completed, the cream is run into vats where it is ripened for the churning operation. The degree of ripening depends upon the type of butter required, some markets demanding a mild- or medium-flavoured article, while others require a full-flavoured butter. Two methods of ripening are used in the preparation of cream for manufacture into butter. These are:

(*a*) Natural Method.
(*b*) Artificial Method.

(*a*) *Natural Method.*—This method is used for the ripening of un-pasteurised cream, and is largely the prerogative of the small butter-maker at the farm. As early as 1850, cream for churning was allowed to sour naturally in order to improve the flavour of the resultant product, and a decade later, dairymen in Denmark added butter-milk to the cream in order to hasten the formation of acid. Cream generally contains a greater number of bacteria than milk, due to the centrifugal action which causes the bacteria to adhere to the fat globules and remain entangled therein. The bacteria present in cream are similar to those found in milk, and, during the natural ripening of the cream, these organisms grow in a normal fashion, first fermenting the lactose present, and later digesting the protein. The fat is not attacked by the bacteria, but absorbs the by-products of bacterial growth, which in turn imparts flavours to the cream. Thus, lactic-acid bacteria impart a pleasant taste to the fat, while organisms of the coli group form acetic and formic acids, in addition to lactic acid, which cause the fat to have an offensive taste and a pungent odour. The rate at which the organisms grow, and the determination of the type which will probably predominate at the conclusion of the ripening period, depend upon the temperature at which the cream is stored. The lactic-acid organisms, which are most to be desired, steadily increase during the first forty-eight hours, after which time the numbers diminish. The cream thickens when bacterial growth is at its maximum, and it is essential that bacterial growth should then be retarded, as, for example, by churning. If this is not done, unwanted organisms, which may readily spoil the resultant butter, may develop.

When this method is in use, the normal practice is to mix together two or three days' supply of cream, the whole being churned on the third or fourth day. The mixture is thoroughly stirred following the addition of each batch of fresh cream, in order to ensure level ripening. Ten to twelve hours should elapse after the last batch of fresh cream has been added before churning takes place. When the cream is ripening, it should be maintained at a temperature of 55° to 60° F., this temperature varying according to season. The cream should be stirred several times daily and should be covered, in order to protect it from contamination. The ripening process proceeds naturally, as the lactic-acid and other organisms in the cream multiply. Ripe cream should have a fresh, acid flavour, be smooth to the palate, and should possess an acidity of approximately 0·5 per cent. The ripening process may be somewhat accelerated if butter-milk is added to the cream, but this method is not to be recommended. Natural ripening, carried out in the manner described, possesses certain inherent disadvantages. If the cream contains any harmful bacteria, their multiplication during the ripening process may result in the production of a butter which possesses a poor flavour and which will not keep. Probably the greatest disadvantage lies in the fact that it is not possible to control the growth of the lactic-acid organisms.
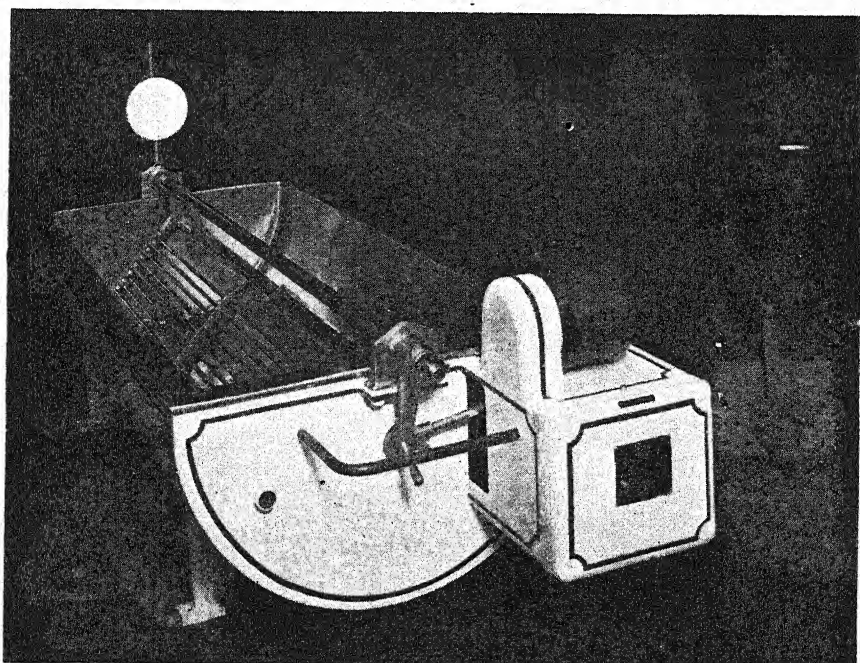
By courtesy of the Aluminium Plant & Vessel Co., Ltd.

FIG. 38—Cream-ripening Vat

(b) *Artificial Method.*—In creameries and butter factories where large quantities of cream are dealt with daily, the natural method of ripening cannot be used. This method has therefore been replaced by the use of artificial ripening cultures. The flavour of the resultant product depends upon the "starter" added to the cream, and to produce a full-flavoured

butter it is essential that the cream should be soured by added "starter." Extreme care is necessary in adding "starter" to cream in order to avoid the development of off-flavours which may be transmitted to the final product. The butter-maker is limited in most cases to the use of a "starter" which has not been incubated more than sixteen to twenty-four hours. A high-acid forty-eight-hour culture will contain an increased amount of diacetyl but it may, if used, impart a cheesy flavour to the butter. Most creameries possess their own type of artificial culture and propagate their "starters" by means of whole or skimmed milk. The method usually adopted is to heat a quantity of separated milk to 150° F. for twenty minutes, this milk being then gradually cooled to a temperature of 70° F. in summer and 75° F. during cold weather. The artificial culture is added to this milk, the whole being well mixed. This mixture is allowed to stand at room temperature (approximately 60° F.) for twenty-four hours, in order that the milk may thicken. A further batch of separated milk is treated in a similar manner, and to this is added a small quantity of the thickened milk. After thorough mixing, the whole is allowed to stand for a further twenty-four hours, when the "starter" is ready for use. A portion is added to the cream, which has previously been pasteurised and cooled. The quantity of "starter" required varies, but as much as 10 per cent. may be necessary with pasteurised cream, although the percentage will usually be less. The cream is then allowed to ripen at a temperature of 60° to 70° F. until the desired acidity has been obtained. This acidity varies according to the quality of the cream used and the type of butter required. The "starter" is usually renewed daily in summer, and two or three times per week in winter.

If desired, a pure culture "starter," composed of true lactic-acid bacteria, may be used. This type was first produced by Storch, a Danish bacteriologist, in 1888, while Conn in the United States of America, and Weigeman in Germany, also demonstrated the use of pure lactic-acid cultures about the same time. These usually contain several types of lactic-acid organisms, the effect of the action of the several species being to produce a more satisfactory degree of acidity in the cream. These cultures are sold commercially either as a powder or in liquid form.

Extended use is being made of "starter" distillates for ripening purposes. Nothing can be added to a "starter" which is to be used in cream to stimulate or increase the yield of diacetyl or the flavour and wholesomeness of the butter may be affected. Butter is not affected in this way when "starter" distillates are employed and a "starter" may be allowed to ripen for the maximum production of diacetyl and, in addition, non-volatile oxidising agents may be used to increase the production of this substance. The process of distillation produces a sterile product with the elimination of any possibility of added yeasts, moulds or undesirable bacteria. In production, the "starter" is placed in a still which is provided with steam and condenser connections. Live steam is admitted and the "starter" allowed to boil, the vapour emitted being condensed to form the distillate. The acidity and diacetyl content of the distillate is usually standardised in the laboratory, so that the amount of flavour added to butter may be controlled.

(4) Churning.—The average temperature at which cream may be churned varies from 50° to 65° F., lower temperatures being required during summer than winter. The optimum temperatures vary from 58° to 65° F.

in winter, and from 50° to 57° F. in summer. In Denmark, churning temperatures vary between 48° and 53° F., according to season. The temperature of the ripened cream is either raised or lowered as required before churning commences, the cream being well stirred during the entire process. If the churning temperature is too high, the resultant product will be soft, oily and grainless, and considerable fat will be lost with the butter-milk. On the other hand, too low temperatures cause churning to be prolonged, the grain being small and difficult to make up, while the texture will be spoiled by friction. Hot water or brine is used for this purpose according to circumstances, the heating or cooling agent being circulated through coils in the ripening vat. Cream which is of too thick a consistency is usually thinned down with cold water, but this addition should not exceed 10 per cent. of the total bulk. The cream should be stirred as the water is added and, before churning is commenced, should flow freely through a straining cloth. The addition of too great a quantity of water will cause the butter to be tasteless and of poor appearance.
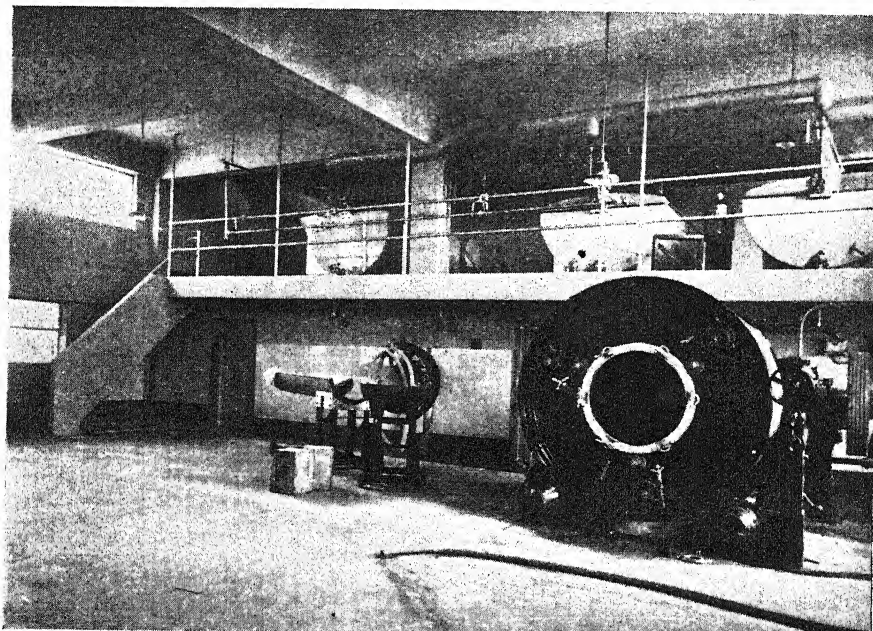
By courtesy of the Milk Marketing Board

FIG. 39—Butter-making Plant

When the ripening process is complete, the cream is strained into churns which have been rubbed internally with salt. It is important to remember that the churns should never be more than half-filled, otherwise the force of impact upon the sides of the churn will be diminished, when the entire process will be unduly prolonged. The churns are usually filled to a capacity varying from one-third to one-half of the whole. They are rotated slowly at the commencement of churning, and are frequently ventilated. They are finally closed down and rotated at more rapid speeds, such speeds being regulated according to the type of churn used. Quick churning provides small grains of butter, and if the churn is revolved at uneven speeds, large

grains will be produced, while agitation is reduced if low speeds are used. The speed at which butter is produced varies in accordance with certain factors, as follows:

(a) Type of churn used.
(b) Temperature.
(c) Ripening and viscosity of cream.
(d) Richness of cream.

Cream separated from milk produced by either of the Channel Islands breeds, possessing, as it does, large fat globules, produces butter much more readily than do milks with small fat globules, such as those from Friesian or Ayrshire cattle.

The more acidity the cream possesses, the more quickly will it churn into butter, but it should be remembered that any excessive acidity will result in coagulation of the casein. This may become incorporated in the butter and is very difficult to eliminate after the butter has been manufactured.

The action of the churn results in violent agitation of the fat globules contained within the cream. These globules gradually coalesce and form granules. The butter will appear in approximately twenty-five minutes, this time varying slightly according to circumstances. When the butter "breaks," i.e. when the cream is changed into granules approximately the size of small peas, churning should be stopped. This change is easily noted by the clearing of the glass inspection window fitted to the churn and by the thudding of the broken cream as it falls within the churn. When any doubt exists as to the "breaking" of the butter, the churn may be opened and its contents inspected. The butter-milk will now have lost its creamy appearance and will appear as a bluish, watery liquid.

When butter makes its appearance, it is usual to add cold water to the churn. This water, which should be of satisfactory quality, possessing a lower temperature than the temperature within the churn, assists in the final separation of the butter-fat from the cream. Churning should never be carried on until the butter is present in lumps. If this point is neglected, the casein will be incorporated in the mass, when the keeping quality of the product will be seriously impaired.

The accurate determination of the amount of butter to be obtained from a given quantity of milk, or as it is often termed, the butter overrun, is extremely important as this is an index of the efficiency of the plant, and the following formula, devised by P. Dornic in 1896, is often used for this purpose.

$$B = \frac{M \times p \times c}{100}$$

where B = weight of butter in lb.   M = weight of milk in lb.
       p = butter-fat percentage of milk.   c = Dornic coefficient.

The Dornic coefficients are set out in Table 10 below.

TABLE 10

Butter-fat Content of Milk—Per cent.	Overrun Coefficient—Per cent.
3·0	1·08
3·5	1·10
4·0	1·11
4·5	1·12
5·0	1·13
5·5	1·14
6·0	1·15
6·5	1·16
7·0	1·17

Various types of churns are in common use, and these may be either constructed of wood or metal. A few modern factory-type churns are now constructed of metal, but the wooden type are most widely employed. Wooden churns require to be prepared for use by soaking with cold water which should be drained off at frequent intervals and replaced so that any odours present in the wooden material are removed. Cold water swells the wood more gradually than does hot water and a more even expansion takes place. When an adequate soaking has been given, the churn should be thoroughly scrubbed with hot water. Persistent odours in the wood may be removed by the use of chlorine solutions, the application of which should be followed by repeated washings with hot water. Churns which have not been used for some time need similar careful preparation. Plenty of time should be allowed for this operation or the cream may enter the pores of the wooden surfaces and become a constant source of trouble.

The *farm-house churn*, one type of which is illustrated in Fig. 40, is usually constructed with an oak barrel balanced diagonally and revolving upon two lugs which rest on a pitch-pine frame. This type of churn is generally revolved by hand, although it can be adapted for mechanical power if required, and it is almost exclusively confined to a capacity of 56 lb. of butter or under. The use of such a churn requires the provision of separate apparatus for "working" the butter, as it is not usual to provide the wooden rollers necessary for this purpose within this small type of churn.

The larger, mechanically operated churns, first developed about 1880, such as are installed in creameries, are very different from the small hand-operated variety. Various modifications differentiate one make from another, but the principle varies only in comparatively slight degrees. They are usually constructed of teak, which has taken the place of oak for this purpose, although Californian redwood is used to some extent. Metal churns have come into use in some butter-making factories during the last decade. These large churns usually contain wooden paddles or rollers, which revolve on horizontal axes and, in the course of their revolution, "work" the butter. Many makers prefer to use several rollers up to six in number for this purpose, and these have proved quite satisfactory.

By courtesy of G. Llewellin & Son.

FIG. 40—Hand-operated Churn

They are the usual type of churn found in creameries in this country.

There has been a tendency during the last few years to give preference to what is known as the *"single-roll churn,"* as illustrated in Figs. 42 and 43. Several adequate reasons exist for this preference.

The single-roll system has proved exceedingly dependable, uniform, and satisfactory for the treatment of butter after the churning process has been completed. Churning itself is simply a matter of agitation and concussion, following the satisfactory ripening of the cream at a suitable temperature. The working process, however, is an entirely different proposition. Gentle, constant, and uniform pressure is required, and it is essential that this should be applied in such a way as not to destroy the fine, natural grain of the butter.

Dairy engineers have endeavoured to simplify churn construction by developing a *roll-less type*, and although these have only been available for a short time, they are being accepted by butter manufacturers, being simple to operate, easy to clean, and capable of turning out a high-class product. The principle of churning is by concussion and working is accomplished by the interior construction of the churn which causes the butter to drop violently from one shelf or corner of the apparatus to another, and such working action is stated to be extremely effective.
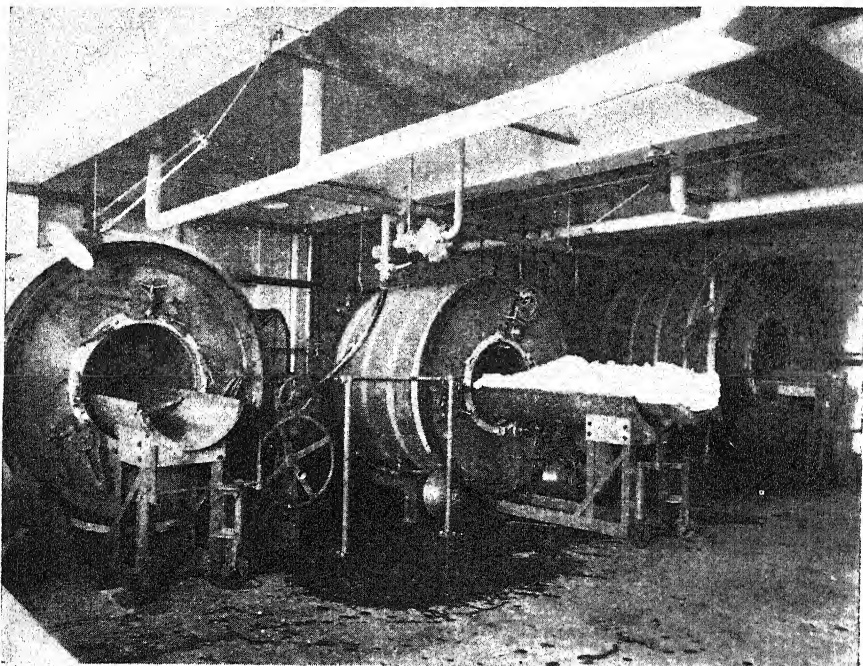
By courtesy of the Milk Marketing Board

FIG. 41—Factory Churns

The grain in butter can be ruined in any one of the following ways:

(*a*) By churning the cream at too high a temperature. This, however, seldom occurs, as all butter-makers appreciate the fact that temperatures must be closely watched when cream is being churned.

(*b*) By improper working, which is more difficult to avoid.

Multiple-roll churns depend upon correct mechanical alignment to produce uniform results. When the churn has been in use for some time, gears become worn, chain sprockets begin to show defects, while the rollers will also wear somewhat on their shafts. Thus, the perfect matching of the roller fluting, which was originally calculated to provide a uniform space at all times, will vary. The spacing between the two rolls at their ends will also vary, when the butter will undergo excessive pressure at one extremity of the churn, and will tend to work towards the other end of the apparatus. This produces lack of uniformity in the moisture content and in the distribution of the salt throughout the finished article. This will occur irrespective of the capabilities of the operator. In many makes of multiple-roll churn, the butter is delivered to the rollers in an irregular manner, the result being

that a certain portion is worked more than the remainder. There is also a tendency for the butter to slide down the side of the drum as it revolves, the grain being thus affected. Where the butter rests for a period against the revolving rolls, the grain and quality are damaged by the continuous rubbing received during the time which elapses before the rolls reach a position which will allow the butter to pass through.
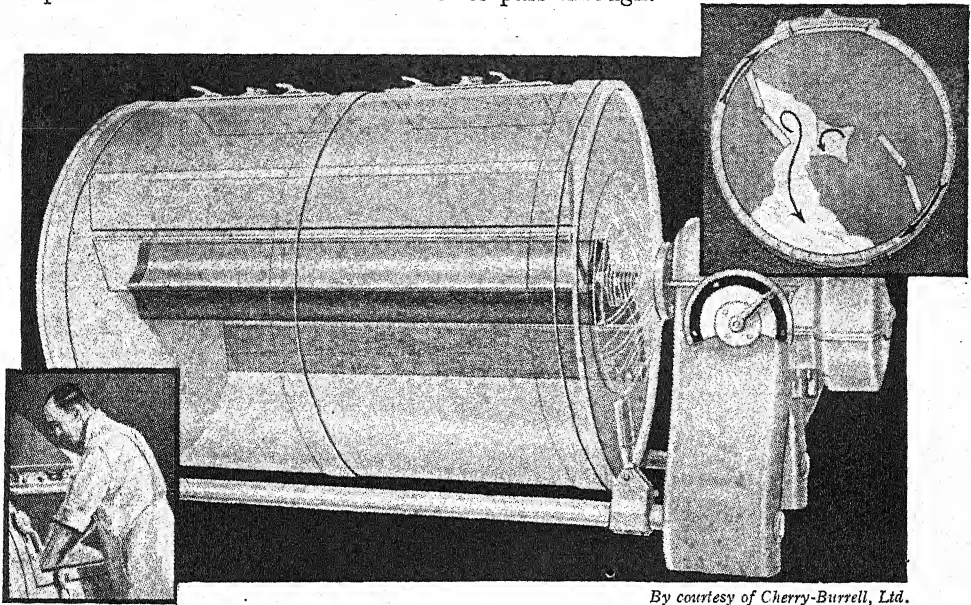
By courtesy of Cherry-Burrell, Ltd.

FIG. 42—Single-roll Churn

With the single-roll churn, all the butter is worked in the centre of the drum. When it has passed between the roll and the shelf (see Fig. 43), the butter drops on to the opposite side of the churn and is immediately picked up by the corresponding shelf and delivered again to the roller. In addition, the water which is carried up with the butter is worked into the mass. The butter is not allowed to churn around in the water, nor is any working pressure applied when the butter is more or less submerged at the base of the churn. From a cursory inspection of the illustration to which reference has already been made (Fig. 43), it would appear that the butter is dragged off the shelf by the roll. This, however, is not so. The shelves are permanent, being fixed to the sides of the drum, but, as this itself is constantly in motion, each shelf is continually changing its position in relation to the roller. As each shelf moves upwards along the side of the drum, the ribs of the roller come over and press the butter against the shelf. This action is equivalent to that provided by two rollers, while, in addition, the roller and the shelves cannot lose their

By courtesy of Cherry-Burrell, Ltd

FIG. 43—Single-roll Churn
(Cross-section)

alignment. Another important point is the fact that the butter alternates in position each time it passes between the worker and the shelf. Thus, the first batch of butter going through between shelf No. 1 and the roller will be the last to go through between shelf No. 2 and the roller, during the second half of the revolution. In this way the butter is worked twice at each revolution of the drum. In view of the aforementioned advantages, the single-roll type of churn is enjoying increasing popularity both in this country and in America.

Difficulties in churning cream into butter may be experienced at all periods of the year, but occur much more frequently during the winter months. The principal difficulties encountered are:

(a) "Sleepy" Cream.
(b) "Frothy" Cream.

(a) *"Sleepy" Cream.*—During churning operations, the cream often becomes sticky and adheres to the sides of the churn, with the result that it cannot be churned into butter. This trouble may be due to any of the following causes:

(i) The use of cream at too low a temperature at the commencement of churning.
(ii) The thickness of the cream. If too thick or kept too long before being churned, the cream is likely to become unworkable.
(iii) Failure to ventilate the churn at the commencement of operations.
(iv) Use of detergents when washing out churns and failure to remove all traces of same.
(v) Overfilling of churns, which unduly prolongs the churning period.
(vi) Overfeeding of concentrated foods to the dairy herd supplying the milk.

"Sleepy" cream may often be avoided by reversing the churn for a few revolutions, but should this procedure fail, the churn should be opened and a small quantity of warm water added to the cream. This water should possess a higher temperature than that of the cream. During hot weather, cold water should be added. If those methods still fail, the cream should be removed from the churn, scalded, cooled to the requisite temperature, and re-churned.

(b) *"Frothy" Cream.*—Cream may become frothy for the following reasons:

(i) Improper natura l ripening.
(ii) Faulty churning temperature.
(iii) Cream too thin.

If the cause of frothiness appears to be due to improper natural ripening, artificial ripening cultures should be used, these being added to the cream *after* it has been scalded and cooled. The temperature of the cream may be raised or lowered to the requisite temperature by the addition of hot or cold water. If the cream is too thin, it should be removed from the churn and warmed to the proper churning temperature.

The whole process of butter making may occupy anything between forty to sixty hours, and for this reason many attempts have been made to accelerate the production of this article. The methods practised in Germany during the War and outlined on page 133 are examples of this, but the most noteworthy attempt has been made in Switzerland following suggestions by Professor Wiegener of Zurich and their further development by Dr. J. Senn. In this process, carbon dioxide is employed for the instantaneous

ripening and coagulation of fresh sweet cream in an apparatus constructed by Escher-Wyss of Zurich. Cream is separated from milk in the normal manner and enters stainless steel containers together with carbonic acid gas under high pressure. Still under pressure, the whole passes to a churn provided with special stirring and battering machinery, and under the constant gas pressure the cream is converted into butter in the short space of one minute. The butter-milk is drawn off and the butter granules are thoroughly washed in running water. A second wash is given in the hardening trough. The granules are then pressed together and immediately packed. Ripened cream can be used in place of sweet cream if desired, and it is stated that 3 per cent. more butter is obtained by this process than from the same quantity of cream treated in the normal way. If these claims are substantiated, it seems likely that present methods of manufacture may be superseded by this apparatus. The finished article complies in every way with statutory requirements as to moisture content and the flavour is said to be greatly improved by this treatment.

(5) **Washing and Salting.**—When the churning process has been completed, the butter-milk is drawn off from the bottom of the churn through a fine-mesh strainer, and the butter is washed with pure clean water to remove the butter-milk as completely as possible. Water is added to the churn, which is then sealed and revolved some twelve times. Care must be taken to ensure that the butter is not churned during the process as this may occur if the temperature of the washing water is too high. On occasion, the temperature of the washing water may need to be higher than that of the butter, although extremes of temperature must always be avoided. Two washings are usually sufficient to remove all traces of butter-milk. After the final washing, the water should be clear when it leaves the churn. Care must be taken not to over-wash butter as this tends to remove the aroma and flavour. During this process, the grain of the butter may be hardened by reducing the temperature of the washing water. Alternatively, the temperature of the water must be raised if the grain is to be softened, but this temperature must not be excessive, for the reason previously indicated. The temperature of the water used for washing the butter is generally between 50° and 55° F.

After the final washing of the butter with cold water, the product is often washed with brine to improve its "body" and to impart a pleasing flavour. This is carried out by allowing the butter to soak in the brine for approximately fifteen minutes, the butter being completely immersed. Such a procedure enables the brine to be distributed evenly throughout the butter.

The manufacture of *salt butter* is usually carried out by the addition of salt to the butter while it is in the grain, prior to its being worked. For mild salt butter, one-quarter of an oz. is added for each pound of butter, while half an oz. of salt per pound is required for medium salt butter. Dry-salting is the method usually adopted for this purpose, it being essential that only fine, dry, clean salt should be used. The subsequent working of the butter incorporates the salt throughout the mass. The working of the butter should not be completed at one operation, as, if the salt is not given time to dissolve, the butter may be streaky. The butter is usually allowed to stand after it has been half-worked for approximately thirty minutes. Butter which is dry-salted keeps better than does the brine-salted product, and for this reason the former method is generally preferred.

(6) **Working.**—It is essential that the butter should be thoroughly worked, but, during this process, the pressure applied should be such as will cause the minimum of injury to the grain. The object of this process is to render the butter compact, to remove any surplus butter-milk which may be present, to distribute the moisture uniformly, and, in the case of dry-salted butter, to incorporate the salt in a thorough manner throughout the product. (Butter when sold must not contain more than 16 per cent. of moisture. The moisture content of good-quality butter seldom exceeds 12 to 13 per cent.)
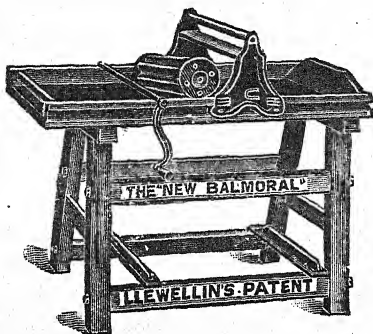
By courtesy of G. Llewellin & Son

FIG. 44—"Balmoral" Butter Worker

At creameries and butter factories, the churn and butter worker are usually combined in one apparatus, but, at the farms, a separate worker, similar to that illustrated in Fig. 44, is generally adopted. It is essential that the treatment prescribed for new churns set out on page 141 should be used for new workers. In the latter apparatus, the butter grains are massed together on the worker, the mass being passed backwards and forwards through wooden-toothed rollers. The action of these rollers expels the surplus moisture and disseminates the salt throughout the substance. The butter worker should be slightly damped before being used, in order to prevent any butter adhering to it.

When butter is being prepared at a creamery, it is considered important that, although the legal limit as to moisture content should not be overstepped, this limit should be approached as nearly as possible, in order to permit of maximum profit. The correct amount of working can only be determined by experience, under- or over-working affecting the body and the texture of the finished product. Insufficient working causes uneven texture, free moisture and leaky butter, while if the product is over-worked, it will be sticky.

A simple test for the presence of loose moisture in butter, due to unsatisfactory working, is as follows. One half-pound block of butter is partially cut in half and then completely divided into its two equal portions. If excessive moisture is present, this will exude from the broken sections.

(7) **Making-up and Wrapping.**—When the butter is dry and firm, it is made up at the farm-house on a butter board into various shapes, such as bricks, rolls, or curls. Half-pound rectangular blocks are the commonest form, being very easily made and facilitating wrapping and packing. Wooden butter-pats, known as "Scotch Hands," are used for this purpose. After wrapping, the blocks require to be hardened in a refrigerator.

When the working of the butter has been completed at the creamery, it is discharged into small trucks, from which it is weighed off into half-hundredweights, being packed into suitably sized containers. There is, however, a considerable demand for butter made up into $\frac{1}{2}$- or 1-lb. blocks. The selling value of butter is enhanced by neat moulding and attractive packing. This is achieved by means of a moulding machine, examples of which are illustrated in Figs. 45, 46, and 47. This apparatus resembles a

sausage-making machine, the butter being fed in at the upper extremity, and propelled forward horizontally through a square aperture. The butter issues from this aperture in a column of square section. This long block is then divided by wire into ½- or 1-lb. blocks as required. These blocks are finally wrapped either by hand or automatically.
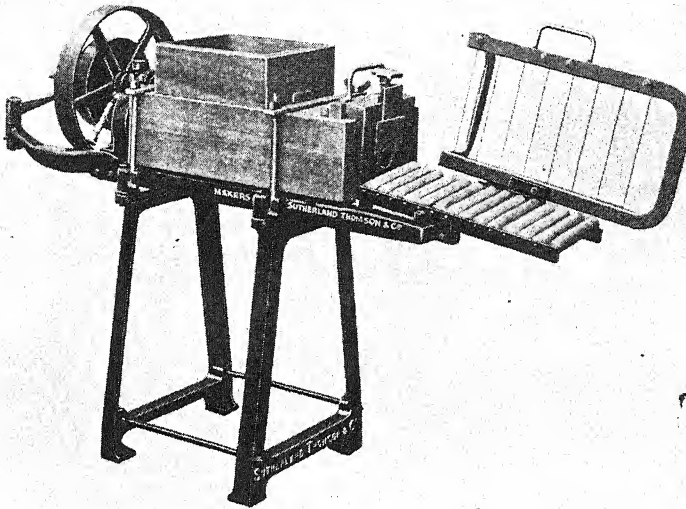
By courtesy of Sutherland Thomson & Co.

FIG. 45—"Omega" Butter Moulding and Cutting Machine

The quality of the *wrapping paper* is important, as it may be a serious source of contamination. Only the best-quality vegetable parchment paper should be used, the so-called greaseproof paper being cheaper but unsuitable for this purpose. Vegetable parchment papers should not support mould growth. Many parchment papers contain glucose and are therefore somewhat unsatisfactory, only such papers as are free from added sugar being entirely adequate. This type of paper is occasionally brittle and possesses a hard texture. Paper of this quality should most certainly be rejected. Wrapping papers should be protected from dust during storage or they may become contaminated with yeasts, moulds, or bacteria. Wrappers for salt butter are often sterilised by boiling in brine solution while those for use with unsalted butter are soaked in boiling water.

Butter in half-hundredweights or in small ½- and 1-lb. blocks is usually packed for distribution in fibre board boxes. These are low in price and quite satisfactory for their purpose. Some butter is, however, packed in wooden tubs or boxes, and these containers should be properly cared for in order to render them sterile. Wooden containers are usually sprayed with paraffin wax which seals the pores in the wood and provides a smooth, clean surface. Wood or timber taints may be avoided by spraying the internal surfaces with casein, which is afterwards hardened by means of formaldehyde vapour. Parchment linings or linings interleaved with metal foil are employed in addition, and these must be chosen and cared for in a similar manner to wrapping papers. Care should be taken to

ensure that no pockets are left during packing in which moulds might develop. After packing, the butter is generally removed to a cold store, where it is allowed to harden until ready for despatch.
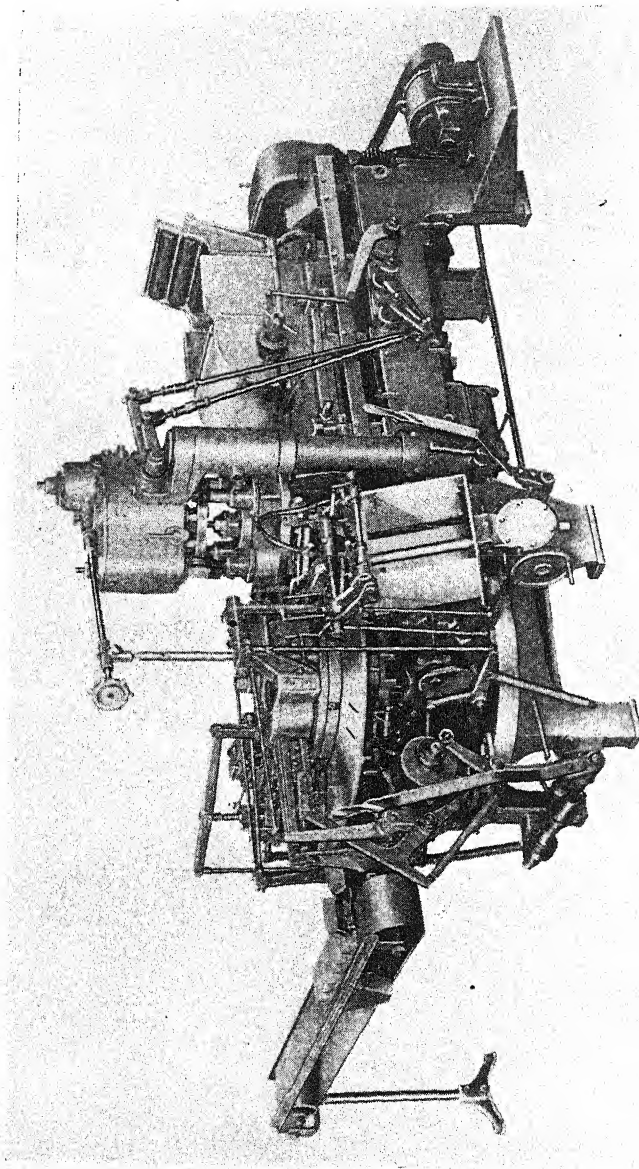
FIG. 46.—"Standard" Butter Moulding and Wrapping Machine

By courtesy of Sutherland Thomson & Co.

Cleansing of Plant

When the butter-making operations have been completed, the utensils and apparatus require thorough cleansing and sterilisation. They should be well washed with cold water, and then with very hot water to remove all grease. They should finally be scalded or, preferably, sterilised with steam or chlorine solutions. As previously stressed, no satisfactory means
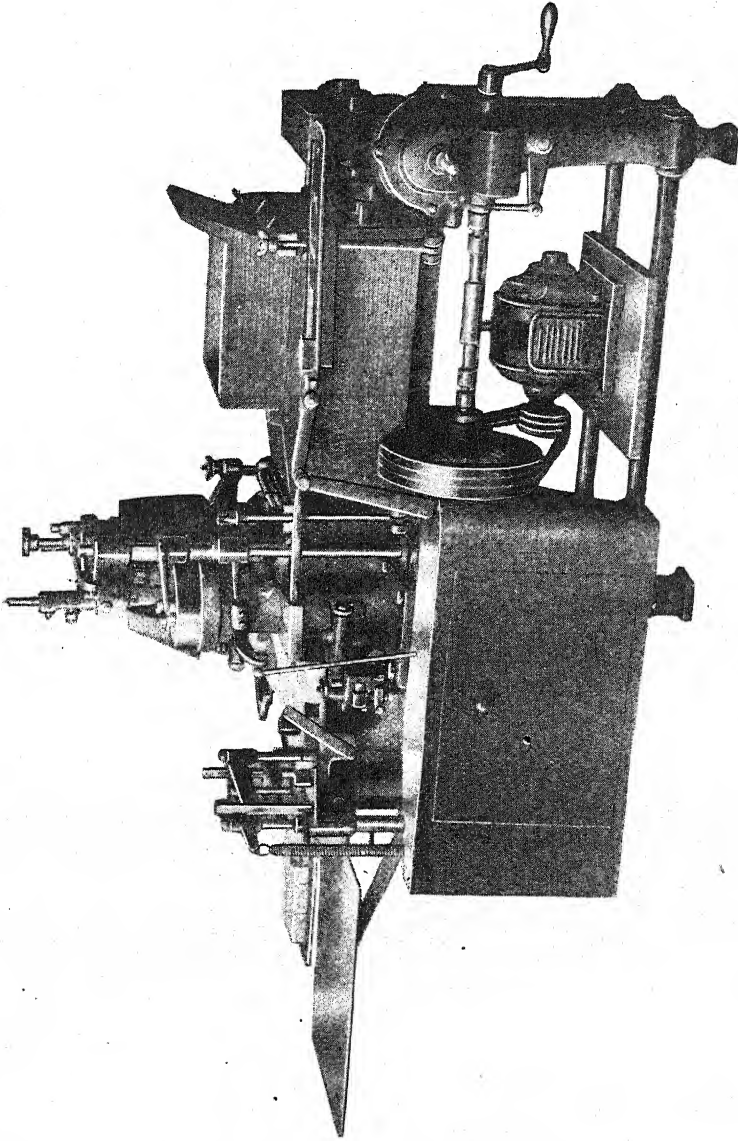
FIG. 47—"Simplex" Butter Moulding and Wrapping Machine

By courtesy of Sutherland Thomson & Co.

of treatment exists which does not make use of efficient sterilisation. Particular care must be paid to the cleansing and sterilisation of the separator, the churn or churns, and the butter worker, if this is a separate piece of apparatus. The *separator* should be washed and sterilised immediately after each run is completed. In too many cases it is found that this apparatus is allowed to remain in a dirty condition until required for further use and traces of milk or cream which remain on the discs and in the bowl become sources of large numbers of bacteria which will inoculate the next batch of milk passing through. Clean milk passing through an unwashed separator will become sour in a relatively short time. The separator bowl should be dismantled and washed in cold water to remove the milk film. Hot water should then be employed for a secondary washing and all parts brushed with

a stiff brush. After this treatment is completed, all parts should be efficiently sterilised, when the separator can be reassembled. The frequent use of chlorine solutions forms an additional safeguard.

The cleansing of *churns* is extremely important and must be carefully carried out. When churning operations are completed, the apparatus should be scrubbed carefully with hot water to remove all traces of fat, or what is known as a "sticky churn" will result due to the fat residues forming a surface to which the fat in the butter will adhere during a subsequent churning. If the wooden surface is perfectly clean, no adherence will occur. The churn should then be scalded or sterilised with chlorine solution and allowed to dry, after which it should be inverted to prevent the entrance of dust and dirt or, alternatively, the opening should be screened. Neglect to efficiently cleanse a churn causes wastage of butter owing to the fact that it will stick to a dirty surface, and where cleansing operations have been neglected for some time, a good detergent solution must be used in conjunction with hard scrubbing.

Butter workers must receive the same scrupulous attention as the churns. When the worker is an integral part of the churn, as is often the case with factory-type apparatus, it is cleansed and cared for in conjunction with that apparatus. In small plants, the worker is usually a separate piece of apparatus and, as with the churn, lack of thorough cleansing will result in a wastage of butter due to its adherence to the rollers, to which particular attention must be paid. All surfaces should be treated as set out for churns above, and before such apparatus is again used it should be scalded with hot water, being finally thoroughly chilled with cold water.

Utensils used for the manufacture and storage of the "starter" demand constant care and scrupulous attention to cleanliness if the "starter" is to remain pure for any length of time. Thorough cleanliness is absolutely essential if butter of suitable texture and quality is to be produced.

Faults in Butter

Butter, in common with other foodstuffs, may exhibit a variety of faults, due to numerous causes. In the case of butter, these deficiencies are chiefly due to errors in manufacture and to undiscoverable defects present in the original raw materials. They may be divided into two classes as follows:

(1) Faults in flavour.
(2) Faults in appearance.

(1) **Faults in Flavour.**—Butter may exhibit a variety of *taints*, due to improper handling of the raw materials or of the finished article. The common taints are:

(a) Sourness.
(b) Bitterness.
(c) Food Taints.
(d) Staleness.
(e) Rancidity.
(f) Insipid Taste.
(g) Tallowy Flavour.
(h) Fishiness.
(i) Saltiness.
(j) Scalded Taste.

(k) Heated Taste.

(l) Wooden Taste.

(m) Oiliness.

(n) Cheesiness.

Most of the abnormal flavours or taints are accentuated by heating.

(a) *Sourness.*—Sourness is due to excessive acidity. This taint is generally due to a faulty cream supply, too great a percentage of acidity having been allowed to develop in the cream prior to churning.

(b) *Bitterness.*—This defect may be due to either feeding-stuffs or to the ripening of cream at too low a temperature. Contamination of the cream supply by bacteria of the *Bacillus coli* group and by certain moulds will cause bitterness to develop. Impurities in the salt used or excess of salt are also contributory causes. An impure water supply may also give rise to this taint.

(c) *Food Taints.*—These may be many and varied, and are generally due to excess of certain foods in the rations of the milk-producing animals. Roots, silage, and highly-flavoured cakes, together with artificial foods, may give rise to taints in the finished article. The consumption of various plants, such as garlic, wild mustard, cress, turnips, or swedes, may also cause an unpleasant taint. To prevent the occurrence of these difficulties, the feeding-stuffs of the milk-producing herds should receive attention, and fresh pasturage should be found if at all practicable. Aeration of the milk and also of the cream by running over a surface cooler is beneficial, many volatile food taints being dissipated in this manner. The quick ripening of the cream is also of great assistance in this respect, while the churning of the cream in small quantities, with frequent ventilation of the churn, will encourage the escape and diffusion of any gases which may be present. It should be remembered that milk, cream, and butter will absorb offensive and unpleasant odours when allowed to stand in proximity to strong-smelling foodstuffs and other articles. In many butter factories, food taints and flavours are now being removed from the cream by subjecting it to a vacuum process.

(d) *Staleness.*—A stale flavour is commonly met with in butter during hot, sultry weather, and may be due to either of two causes:

(i) Poor-quality cream, in which case the newly churned butter will show evidence of staleness.

(ii) The storage of butter for lengthy periods at varying degrees of temperature.

It is essential that only cream of the highest quality should be used, and that all butter should be stored after manufacture at a constant temperature.

(e) *Rancidity.*—Rancidity, which is a frequent cause of consignments of butter being condemned, may be regarded as the final stage of staleness, and is the result of decomposition of the butter-fat into glycerine and fatty acids, and of oxidation. This taint is often observed in varying degrees during hot weather, and presents considerable difficulties in the way of elimination. It may generally be assumed to indicate advanced deterioration of the product. Rancidity and moulds are closely allied.

(f) *Insipid Taste.*—Butter which can be described as "insipid" possesses a poor flavour, somewhat similar to that of margarine. Several reasons for this insipid taste exist, as follows:

(i) Use of cream which has been insufficiently ripened.

(ii) Feeding of rank herbage to the herd supplying the original milk

(iii) Overwashing of the butter in the churn or on the butter worker.

There is nothing objectionable *per se* about such butter, but, if the flavour follows the churning of sweet cream, rancidity may result. Insipid butter should be very mildly salted. The flavour of normal butter is improved by the addition of salt, which fixes the flavour. When butter is insipid, there is no flavour to fix or to preserve, and the addition of the normal amount of salt will therefore not improve the resultant product. "Flat" flavour sometimes results from excessive cold storage or develops in butter manufactured from neutralised cream.

(g) *Tallowy Flavour.*—This is considered by manufacturers to be a particularly objectionable flavour. It is a permanent defect, while, further, the texture of the butter will suffer through its presence. Various causes are:

  (i) Use of cream which has been stored for too long a period.
  (ii) Use of cream containing a high fat percentage, particularly during hot weather.
  (iii) Exposure of the cream used to bright sunlight.
  (iv) Use of cream from the milk of cows fed on soft, watery herbage.
  (v) Presence of certain bacteria found on grass.
  (vi) Use of over-ripe cream, rapidly heated and cooled.
  (vii) Presence of copper salts.

If the butter has any tendency to tallowiness, it will show a pronounced flavour following alternate chilling and thawing. If thick cream is being used in manufacture, great care must be exercised in churning and working the product.

(h) *Fishiness.*—A fishy flavour may develop either in salted or unsalted butter, but is more likely to be found in the former product. The two principal causes are high acidity of the cream and high temperature of both the cream and butter. A small mould, named *Oidium lactis*, which makes its home in the woodwork of dairies, will also cause this defect. In such case, the suspected woodwork should be given frequent applications of hot limewash.

(i) *Saltiness.*—As salt is added to butter prior to working, it is essential that the latter should be given a thorough working. Insufficient working imparts an intensifying effect to the salt, such effect being particularly noticeable in "leaking" butter.

(j) *Scalded Taste.*—Cream which has been improperly pasteurised at too high a temperature will impart a cooked or scalded flavour to the butter. This taste is much more noticeable when the temperature of the butter is increased.

(k) *Heated Taste.*—This is particularly evidenced in insipid butter, and is due to exposure of the product to high temperatures. During such exposure, the fat absorbs the heat and produces this taint to a marked degree. This flavour is quite distinct from the scalded taste produced by the over-pasteurisation of cream.

(l) *Wooden Taste.*—This is due to contact with wooden containers during transit. A similar defect is caused by certain types of yeast. When packing butter in wooden containers, care must be taken to ensure that the product does not come into contact with the sides of the boxes. To determine whether or not faulty packing is the cause of the taint, the butter in actual contact with the sides of the box should be carefully tested.

(m) *Oiliness.*—Oiliness may be due either to vegetable or to mineral contamination. The drinking water supplied to the cows, and the water used for washing the butter, form probable sources of contamination. The

taint may also arise following decomposition of the butter-fat, due to organisms contained in the cream supply.

(*n*) *Cheesiness.*—This is due to the use of old, heated cream and to inefficient cleansing of the cream containers. If any traces of cream are left in the ripening vats following cleaning operations, such cream will become "cheesy" in character, and each fresh supply of cream entering the vats will, in turn, be inoculated with the causative organisms. Butter manufactured from cream containing a high percentage of fat is particularly subject to "cheesiness," and, if such butter is exposed to high temperatures, the flavour will become more pronounced.

(2) Faults in Appearance.—Butter may possess a poor appearance because of the following factors:

(*a*) Faulty Colour.
(*b*) Streakiness.
(*c*) Mottled Appearance.
(*d*) "Leaking" Butter.
(*e*) Poor Texture.
(*f*) Presence of Yeasts and Moulds.

(*a*) *Faulty Colour.*—No hard-and-fast rule can be laid down regarding the colour of butter, as a varying demand for peculiarities in colour exists in different parts of the country. For instance, Danish butter, which possesses a deep straw colour, is generally preferred throughout the northern counties, while, in southern England, a pale-coloured product is more popular. Paleness or whiteness in butter is due to various causes. The breed of cow from which the milk was originally obtained will have an appreciable effect, while the feeding of excessive quantities of cake and roots will result in the milk yielding a pale-coloured butter-fat. The season of the year also affects the colour of the butter. Certain additions to the food of cattle during the winter months will deepen the tint, while salt will have a similar effect. Annatto is often added to the cream in the churn to improve the colour. The exposure of cream or butter to daylight will diminish the intensity of the final shade, while overworking the butter will also cause a similar decrease.

An *irregular colour* is sometimes observed. This may arise from lack of care in working, from variations in the consistency of the finished product, or from differences in the butter-fat content of the cream used in manufacture. This irregular colour may also occur as the result of mixing several churnings of butter on the worker. *Discolorations* may also occur due to moulds and to bacteria probably of the *Pseudomonas* species.

(*b*) *Streakiness.*—Streakiness, which is highly undesirable in butter, is generally due to insufficient washing of the product while in the grain, or to over-churning. Those points should therefore receive careful attention. Lack of care in the salting of the butter, and the use of low-grade salt, will also cause streakiness in the finished product. This defect may be prevented by the use of high-grade salt, which should be carefully sifted on to the butter and thoroughly worked into the mass. This defect has decreased considerably during recent years, following the use of modern butter workers.

(*c*) *Mottled Appearance.*—This is usually due to the use of cream which has been unevenly ripened. If this defect is to be avoided, it is essential that cream standing in the ripening vats should be stirred at least twice

daily, to ensure even ripening. Cream which possesses a low density will occasionally separate on standing, when the skim milk will coagulate at the bottom of the ripening vat. When the vat is emptied, the particles of casein are broken up and the cream becomes more finely divided on churning. The resultant butter shows small white specks in its bulk. These may also be present following the pasteurisation of over-ripened cream.

(d) *"Leaking" Butter.*—Butter often contains a relatively high moisture content, and leakage of this moisture may cause loss of weight. Some butters are naturally moist and show an appreciable degree of free moisture without, however, exhibiting any serious shrinkage. Such products should not be confused with "leaking" butter. This defect is attributable to a variety of causes. These are:

(i) *Churning of Cream at Excessive Temperatures.*—To compensate for this, the butter should be washed at very low temperatures. Correct temperature control is essential.

(ii) *Churning of too great a Quantity of Cream at one Time.*—The churn should never be overloaded.

(iii) *Underworking of the Butter.*—This constitutes one of the principal causes of leakage.

(iv) *Storage at Low Temperature.*—Leakage is greater in a humid atmosphere.

(v) *Use of too much Salt.*

(e) *Poor Texture.*—Good butter should possess a smooth texture, firm and close throughout. Relatively excessive temperatures have an adverse affect upon the final texture, a granular condition often resulting. The texture may also be spoilt by churning the cream before it has been properly cooled. Underworking of the butter will result in a loose, open texture. Butter is occasionally "weak-bodied," and exhibits no solidity. If such butter is overworked, it will become moist, soft, or spongy. A low percentage of water usually accompanies a hard-textured butter. Maize, bean, pea-meals, and other dry fodder will harden the texture of butter, while the period of lactation of cows also plays an important part in determining the final texture. A fatty texture is produced by soft butter-fats, heated cream, and high churning temperatures. This condition will increase as the butter ages. Butter may be damaged in texture as the result of overworking. If, however, the butter is insufficiently worked, the texture will also be poor.

(f) *Presence of Yeasts and Moulds.*—Yeasts and moulds produce harmful changes in butter, and entail heavy losses to manufacturers, distributors, and consumers. A *musty taste* is also associated with these organisms which readily enter the milk and cream supply, old churns and butter workers being particularly liable to heavy contamination. Raw cream may also be contaminated in this way, and considerable damage will be produced in butter which is manufactured from such unpasteurised cream, more especially if the product is subjected to high or varying temperatures or if it is stored in damp, badly-ventilated atmospheres. It is a difficult matter to destroy yeasts and moulds when once they have obtained entrance to churns and butter workers. Parchment wrapping paper and salt, if not of the highest quality, may also assist in contaminating the product. The wooden boxes in which butter is often packed may be a source of contamination, particularly if the wood is unseasoned or if it has been exposed to contaminating influences during storage. Parchment wrappers should always be used with wooden containers to prevent any contact

between the butter and the wooden surface, or the internal surfaces of the container should be treated in the manner described on page 147. Yeasts and moulds flourish at a temperature of 50° F., but will grow at comparatively low temperatures. Growths of black or white moulds are sometimes found upon the surface of blocks of butter, their presence being due to contamination in cold stores. Moulds may penetrate an entire box of butter and produce rancidity. All wooden and metal utensils should be efficiently and regularly sterilised to prevent the development of such parasites. Dirty methods of manufacture and laxity in sterilisation are an incentive to their growth, and should not be tolerated. The pasteurisation of cream, followed by the use of a pure culture for ripening purposes, will result in a high degree of purity and cleanliness.

Keeping Qualities of Butter

It can definitely be stated that butter is one of the best foods, as regards keeping qualities, known to-day, but the term "keeping" must be regarded as relative, as butter will not maintain its original condition for an indefinite period. It should be remembered that butter is not protected, as in the case of many foodstuffs, by means of a can. Even if this were so, such protection would be of little assistance, as the bacteria present are distributed throughout the product in a similar manner to that which holds in the case of milk or cream. Before the important part played by bacteria in the decomposition of food was known, and before methods of artificial refrigeration had been introduced, however, it was possible to manufacture butter which would keep for six to nine months.

The theories originally evolved to explain the keeping qualities of butter have changed considerably. Many years ago, unsalted, sweet-cream butter, which quickly became rancid, was considered a delicacy. The consumer generally demanded butter manufactured from properly ripened cream which possessed better keeping qualities. The cream separator was not invented until 1878, and milk was generally sour by the time the cream had risen. This age, it should be remembered, coincided with that unhappy period when clean milk production was unknown. In view of the rapid souring which occurred, sour-cream butter was the type normally manufactured and sold. As the use of separators developed, it became possible to obtain sweet cream. As sour-cream butter was still in demand, however, the sweet cream was rendered artificially sour by the addition of sour milk or butter-milk. When the advantages of bacteriological control were realised about 1890, successful attempts were made to sour cream artificially by the addition of pure cultures of lactic-acid-forming bacteria, and this method was further improved by pasteurising the cream prior to the addition of the artificial cultures.

The general practice of storing butter in cold storage came into being in 1900. This practice possessed the advantage that it allowed butter manufactured in summer and surplus to normal requirements to be stored for winter use.

The efficient pasteurisation of cream destroys approximately 99 per cent. of the existing bacterial content. Considerable advantage is derived from this method of treatment, as, when the "starter" is added, the large proportion of lactic-acid organisms which develop and produce lactic acid suppress any extraneous bacteria which might cause rancidity of the butter,

in addition to those which may obtain entrance to the product during manufacture. Such a procedure, however, is not without its drawbacks. Butter is often spoilt by the presence of yeasts and moulds, which grow more readily in sour milk than the fresh product.

Yeasts and moulds obtain entrance to the product after the cream has been pasteurised. Moulds grow upon the surface of liquids, and it is worthy of note that draughts will carry ripe moulds to any part of the manufacturing premises. The organism *Oidium lactis* might be specifically mentioned. This mould is a common inhabitant of creameries. It grows upon the floors, walls, and ceilings, wherever there is moisture, and also in vats, churns, pipe-lines, and on utensils.

As time passed, the infection of pasteurised cream was found to be a cause of butter spoilage. Later, it was discovered that cold storage, which had been considered a certain method of preventing spoilage, was not a complete success in this respect. Butter constantly deteriorated in cold-storage premises, although bacteria, yeasts, and moulds decreased considerably in numbers. Chemists accordingly set to work to discover the reason for this apparently anomalous circumstance, and it was then found that the acid of sour cream acted upon the lecithin in the butter and produced a fishy flavour. This process is greatly accelerated by the presence of metal, traces of which can scarcely be avoided, as the milk and cream, until churned, are constantly in contact with such substances.

In spite of all defects, butter keeps extraordinarily well, when the conditions under which it is produced and distributed are considered; the unsalted variety exhibiting better keeping qualities than the salted product. When manufactured, butter usually contains any number over 10,000 bacteria per millilitre; it is not sterilised after manufacture, and it is not packed in airtight containers. On the contrary, butter is usually packed in wooden tubs or boxes, and is often cut and weighed without any special precautions being taken.

The reason underlying the satisfactory keeping qualities of butter is its composition. Butter contains at least 80 per cent. of fat, with not more than 16 per cent. of moisture. This moisture is composed of the butter-milk which remains in the product after churning, and the water present after the washing process. Such moisture is distributed throughout the butter in the form of small globules, such bacteria as are present being enclosed within these minute droplets. The degree of infection is decreased if their size is reduced, and this object may be attained by the continued and thorough working of the butter. Overworking is, however, harmful, as the texture suffers, but, if the product is worked to the optimum limit, experiments have shown that bacterial decomposition may be reduced by approximately 40 per cent.

Butter Grading

Many countries which regularly export butter to Great Britain have adopted grading systems. Denmark was the first country to formulate a scheme of this nature, that country being closely followed by others. Grading has been carried out in Ireland for many years, and a national mark for butter has been adopted there. This scheme includes bacteriological examinations of the product. Butter cannot be exported from any of the Australian States unless it has been graded by a Government inspector

and placed into one of five grades, i.e. choice, first grade, second grade, third grade, and pastry butter. In New Zealand, where grading has been in force for many years, the butter is two days old when graded. It may be noted here that it arrives in this country in perfect condition.

When butter is graded, points are awarded for certain conditions, the scale of scoring used by the British Dairy Farmers' Association being as follows:

	Points
Flavour	50
Texture	20
Colour	10
Freedom from Moisture	10
Packing	10
	100

In the case of colonial butter, ten points are awarded for salt, while, if the butter is unsalted, these points are divided between flavour and texture.

Flavour is generally classified under the same heading as *aroma*, although these qualities are entirely separate. Butter is often judged by aroma only, but this practice is exceedingly deceptive, as flavour and keeping qualities may thereby be overlooked. The flavour of butter should be sweet and nutty and free from objectionable taints. The various taints which may be found have already been specified (see pages 150 to 153). It has been found that refrigeration will assist considerably in eliminating plant flavours, and will also tend to reduce deleterious flavours of other types. *Salt* is an ingredient of much of the butter consumed in this country and should be so used that it does not destroy the natural flavour of the product. Butter usually contains from 1 to 3 per cent. of salt, according to the tastes of consumers in various districts.

The *colour* of butter provides a more difficult problem. A clean straw colour is ideal, but, as already indicated, different districts prefer different colours, which they demand from their respective retailers. Any exact shade may be fixed by means of *Hansen's Butter Colour Scale*, which is used as a standard guide in a large number of creameries. There are no restrictions regarding the use of colouring in butter, provided such colouring material is obtained from pure vegetable matter. Defective colours are almost invariably due to faults in manufacture.

Moisture, if excessive, will lose points for butter when it is graded. Excessive moisture, however, can only be correctly determined by chemical analysis.

Packing is an important matter, although superficially this may not appear to be the case. Suitable packing provides a considerable aid to sales, while, if badly packed, the butter may contain air pockets, which will encourage the development of moulds.

Butter is graded by means of a grading iron or "trier." This is inserted at a slight angle throughout the full length of the sample to be examined, after which it is given a half-turn and finally withdrawn. The butter withdrawn with the iron is immediately tested both by smell and taste. At the time of examination, the temperature of the butter should be approximately 50° F. Butter is usually graded when two to three days old, as the flavours should then have had sufficient time to develop properly.

Butter, if manufactured from good-quality cream, suitably and carefully prepared, will keep in cold storage for a considerable period. Fresh dairy butter keeps best at 35° F., the corresponding temperature for imported butter being in the neighbourhood of 20° F. When held in cold storage for six to eight weeks, considerable shrinkage will occur. A 56-lb. box of butter may lose up to 14 ozs. in weight through this cause.
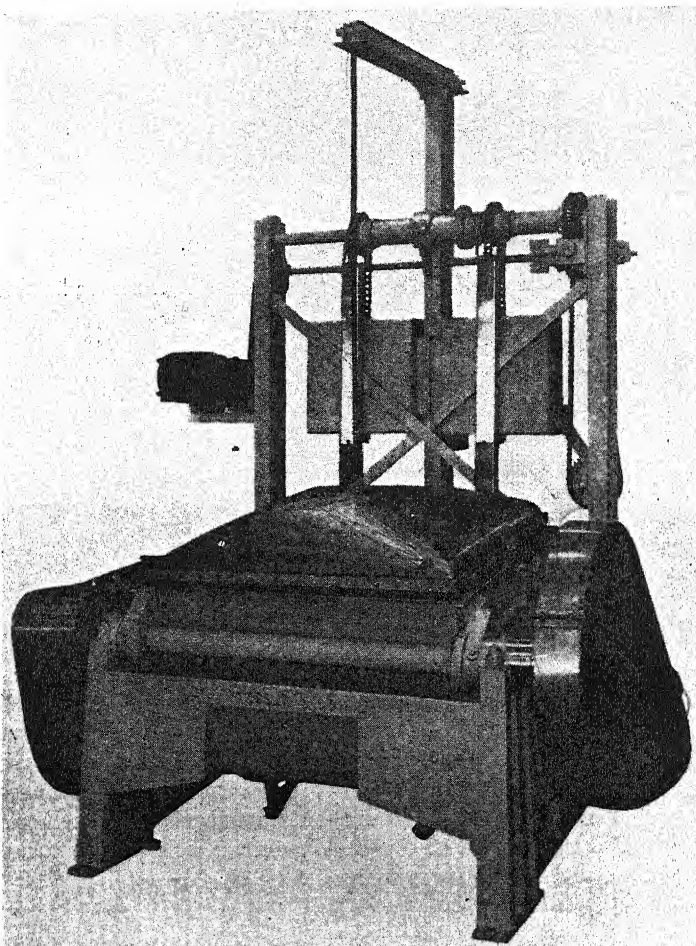
By courtesy of G. J. Worssam & Son, Ltd.
FIG. 48—Butter-blending Machine

Butter Blending

A considerable demand for blended butter exists in this country owing to the desire for a uniform product. To meet this demand, different grades of home-produced, foreign, and colonial butters are mixed together. This process does not improve the resultant blended butter, as it destroys both the texture and the grain. It possesses one advantage, however, in that it allows a uniform article, which is easy to spread, to be produced. The blending process is carried out by means of a machine fitted with revolving blades, which kneads the various batches of butter together. During the

process, additional moisture may be incorporated in the butter. Thus, a dry butter with a low moisture content may be brought up to the legal limit of 16 per cent. Certain types of butter-moulding machines cause a serious loss of moisture, although this loss may be avoided by the incorporation of an excess of moisture during the blending process. Care and cleanliness are essential in blending or the bacterial content may be greatly increased, with consequent deterioration of the final product.

The "Worssam" butter blender, illustrated in Fig. 48, will blend various kinds and grades of butter into a consistent mass suitable for treatment by a wrapping machine which produces packeted butter. The various butters to be blended are fed into the hopper of a shiving machine which delivers the butter in thin ribbons direct to the blender. This apparatus consists of a stainless steel pan which has two agitators, fitted internally, running at different speeds. The pan is provided with a stainless steel cover which remains in place during blending operations. Water and salt are added during the process in order to ensure that the moisture content of the finished article conforms to statutory requirements and the cover ensures that none of the water escapes during blending. The front of the pan is fitted with trunnions and when processing is completed it is tipped and one turn of the agitators discharges the whole batch of blended butter into a truck placed in position to receive it. Both mechanical- and hand-operated tipping is provided. It is important to note that the required consistency is obtained throughout the mass while the moisture is entirely absorbed. This apparatus can also be employed for the treatment of margarine.

Butter-milk

Butter-milk, the most important by-product of butter-making, requires special, if brief, mention. Good butter-milk gives the following analysis:

	Per cent.
Water	91·06
Fat	0·31
Milk Sugar	4·44
Casein and Albumin	3·44
Mineral Salts	0·75
	100·00

Butter-milk is much more easily digested than cows' milk by reason of the fact that the casein is more finally divided. It also contains more iron in concentrated form. Butter-milk is little used in this country as an article of diet, being usually fed to pigs, with the exception of such small quantities as are converted into butter-milk cheese (see page 202). In many countries, however, it is a staple food, and is considered to possess valuable remedial properties. It is used in the treatment for rheumatism, and is also prescribed by physicians for pulmonary affections. An exclusive butter-milk diet has, in many instances, been used with advantage in diseases of the kidney, while gastric acidity may be effectively counteracted by its consumption.

Butter-milk possesses a full flavour and body. Its flavour is due to the acidity present and to those constituents responsible for the flavour and aroma of butter as the majority of these find their way into the butter-milk during churning operations. The finely-divided precipitated casein

in suspension is responsible for the body and any particles of butter-fat present in the liquid will improve its flavour.

In the United States of America, butter-milk is consumed as a beverage in considerable quantities. As it is difficult to obtain sufficient quantities of the freshly-churned article for this purpose, artificial butter-milk is manufactured upon a large scale. This is prepared from newly-separated milk to which a pure ripening culture has been added. The product is ripened at a temperature of 70° F. and, when coagulation takes place, is churned in the ordinary way. From 0·5 to 1·0 per cent. of butter-fat is usually added in the form of cream in order to improve the flavour.

Bacteria in Butter

Bacteria, particularly lactic-acid bacteria, play an exceedingly important part in the manufacture of butter, and also in its spoilation. In good-quality butter which has been manufactured in a satisfactory manner, there is little food present for bacteria other than the fat. Very fortunately, organisms do not readily attack this fat, although it is not secure from attack by various yeasts and moulds. Such other nourishment as may be present is seized upon by the lactic-acid bacilli which form acid by-products. These, in turn, deter the growth of unwanted putrefactive organisms.

The organisms present in butter may be divided into three groups, as follows:

(1) Non-pathogenic Organisms.
(2) Pathogenic Organisms.
(3) Abnormal Bacteria.

(1) **Non-pathogenic Organisms.**—Sweet-cream butter manufactured from unpasteurised cream contains similar organisms to those found in milk, and these will produce similar bacterial changes. At low temperatures, the bacteria normally present in water usually predominate. As the temperature rises, lactic-acid streptococci develop with increasing rapidity. Later, lactic-acid bacilli, yeasts, and moulds appear. Organisms of the coli group are also generally present. The non-pathogenic group of organisms are not of serious consequence to the consumer from a public health point of view, but certain of them may cause the development of rancidity and other defects which will detrimentally affect the keeping qualities of the product.

Butter manufactured from pasteurised, ripened cream possesses a much less complicated bacterial content as regards non-pathogenic bacteria than does the type of butter already described. The principal organism present in this case is the *Streptococcus lacticus*, although heat-resistant organisms are also likely to be present. This organism, however, does not appear to exist for lengthy periods in butter, and is gradually replaced by yeasts and lactic-acid bacilli. The bacteria contained in butter usually develop within the small droplets of water which are present throughout the substance. For this reason, butter produced from pasteurised, ripened cream will never contain the large numbers of organisms usually present in milk or cheese.

Properly-treated butter seldom contains excessive numbers of non-pathogenic bacteria. In sweet-cream butter, the bacterial content increases during the first few days after manufacture, after which it begins to show a decrease. In butter produced from ripened cream, the total count is

highest immediately after manufacture. This is explained by the fact that the lactic-acid organisms are destroyed more rapidly than their successors can develop, since the nutritive matter available for their growth is constantly decreasing.

Non-pathogenic organisms grow much more quickly and more easily in sweet-cream, unsalted butter than in butter manufactured from ripened cream, to which salt has been added. It may be generally stated that lactic-acid bacteria, while promoting the growth of yeasts and moulds, prevent, to a considerable extent, the action of fat-hydrolysing bacteria which are the cause of rancidity. Rogers and Gray have stated that butter manufactured from pasteurised sweet cream keeps much better than that produced from pasteurised sour cream, and that the addition of lactic acid to the pasteurised cream has the same affect as souring with a "starter." It is essential that only pure cultures of good lactic-acid bacteria should be used as "starters." If this is not done, there is a possibility of other unwanted organisms obtaining entrance to the cream after pasteurisation.

(2) **Pathogenic Organisms.**—As is the case with the non-pathogenic group, butter manufactured from unpasteurised sweet cream may contain any of the pathogenic organisms found in milk before separation. Most important among these is the *Mycobacterium tuberculosis*. Savage has stated that he considers 10 per cent. of English butter to be contaminated with living tubercle bacilli, and these can survive for long periods as can *Brucella abortus*. Outbreaks of *typhoid fever* attributable to infected butter have been reported, although such organisms must presumably have obtained entrance to the milk, cream, or butter *after* production, the possibility of an animal source of infection being virtually negligible. Typhoid organisms may survive several days in salted butter and have been isolated from unsalted butter after several months storage. *Corynebacterium diphtheriæ* does not survive for lengthy periods, although one outbreak of disease attributable to this cause has been reported. The causative organisms of food poisoning may survive for many weeks when present.

If butter is manufactured from efficiently pasteurised cream, pathogenic bacteria can only be introduced during the churning, handling, or packing of the product. It is important to remember that butter manufactured from such cream will not exhibit the high percentage of samples infected with tubercle bacilli mentioned by Savage.

(3) **Abnormal Bacteria.**—Defects in butter affecting the appearance and taste of the product have already received consideration (see pages 150 to 155), and it will suffice here to mention that many such defects are due to the action of various types of unwanted, non-pathogenic bacteria, particularly yeasts and moulds. The entrance and growth of these organisms may be prevented if sufficient care is exercised during all stages of manufacture.

Bacteriological Control

The efficient bacteriological examination of butter samples must, as in all similar cases, be carried out to a certain routine, as follows:

(1) Collection of Samples.
(2) Examination for Total Bacterial Count.
(3) Examination for Yeasts and Moulds.
(4) Examination for Specific Pathogenic Organisms.

(1) **Collection of Samples.**—The method of collecting samples for bacteriological examination is quite as important in the case of butter as it is for other milk products, including milk itself. Metal triers, spatulas, and spoons should be enclosed in metal containers and sterilised for half an hour at 180° C., together with the screw-topped glass sample jars. The method of sampling varies according to circumstances, as follows:

(a) *Butter in the Churn.*—Prior to the removal of the butter from the churn, the necessary samples should be taken by means of a sterile trier. Three samples, each of 1 oz., are usually obtained, one from either end of the churn and one from the centre. The butter is then placed in a sterile glass jar, which should be sealed.

(b) *Butter in Tubs or Boxes.*—It is usual to remove 1 oz. of butter from two different parts of the box or tub with a sterile trier. These plugs of butter should be approximately 2 inches in length, and should include the surface portions. The butter is transferred to a sterile glass jar by means of a sterile spoon or spatula. The jar should then be sealed.

(c) *Butter in Small Blocks.*—In the case of butter wrapped in ¼-, ½-, or 1-lb. blocks, a sample portion 3 or 4 inches in length is removed from the centre of the block by means of a sterile trier, and is transferred to the jar, as previously described.

Immediately the samples have been obtained, the containers should be packed in ice for removal to the laboratory, and should reach their destination as quickly as possible. If they are not to be dealt with immediately, they should be stored in a refrigerator (upon arrival at the laboratory) at a temperature not exceeding 35° F. until the examination takes place.

(2) **Examination for Total Bacterial Content.**—As even normal butter may contain a high bacterial content, the estimation of the total number present may yield little practical information. When desired, however, the test may be carried out in the following manner. Five grams of butter are weighed and transferred to a sterile mortar where they are thoroughly pounded with 95 mls. of warm water. It is essential that the sample should receive adequate mixing, as the bacteria tend to adhere to the butter-fat. The dilutions are then made, the plates poured and incubated, and the colonies counted in a similar manner to that described for the routine bacteriological examination of ice-cream (see pages 53 and 54).

Fay has described a method of microscopic examination suitable for research and control purposes. The butter to be examined is melted at 45° C. for a period which must not exceed fifteen minutes, after which it is sufficiently agitated to obtain a homogeneous sample. The detailed examination may be divided into the following stages:

(a) 0·1 ml. of melted butter is placed on a clean glass slide and one drop of xylol, together with one drop of Mayer's egg-glycerine mixture, are added, the latter being used to fix the smear to the slide.

(b) The mixture is stirred with a platinum wire until it is opalescent and homogeneous. It is then spread over the entire area of the slide. The mixing of the sample with the xylol and the Mayer's solution requires two to three minutes.

(c) The preparation is allowed to dry, the albumin being coagulated by placing the slide on a flat bottle of heated water at 80° C., where it is allowed to remain for ten to fifteen minutes.

(d) The smear is then fixed in 70 per cent. alcohol for ten to twenty seconds, and is again allowed to dry.

(e) The slide is immersed in xylol for two minutes and allowed to dry.

(f) The smear is stained with methylene blue for one minute and is afterwards washed. It is then allowed to dry at room temperature

(g) By means of an oil-immersion lens, the field of which has been standardised to a diameter of 0·157 mm., the slide is examined. The average number of micro-organisms per field multiplied by 1,000,000 will give the approximate number present in 2 mls. of melted butter.

(3) **Examination for Yeasts and Moulds.**—The dilutions used for determining the yeast and mould content of butter are usually 1, 0·1, and 0·01 ml., although higher dilutions may be made if desired. Some 10 mls. of dextrose-tartaric acid agar cooled to 40° C. are poured over each dilution, in sterile Petri dishes. The contents of each dish are then mixed, by means of a rotary motion. It is essential that the plating should be completed as rapidly as possible. When the medium has thoroughly hardened, the Petri dishes are inverted and placed in the incubator. The plates are incubated either at 21° or 25° C., for five days. After two or three days' incubation, the plates should be examined to determine the degree of mould growth, and, if large numbers are visible, a count should be made at that stage. This count should be repeated on the fifth day. The yeast and mould colonies are counted by the naked eye, each type being enumerated separately. The separate numbers of yeasts and moulds are then combined to give the total number present.

(4) **Examination for Specific Pathogenic Organisms.**—The examination of butter for pathogenic organisms is chiefly confined to investigation of the presence or absence of tubercle bacilli. The only satisfactory method of carrying this out is by means of animal inoculation, the routine of which has been already described on pages 98 and 99. In the case of butter, the sample is melted, centrifugalised, and inoculated into guinea-pigs. Examination for other pathogenic organisms, such as typhoid bacilli, streptococci, etc., is made in a similar manner to that described in the case of ice-cream and cream (see pages 55 and 97).

Chemical Examination

Butter is sometimes, although rarely, adulterated by the addition of foreign fats, such as coconut oil or margarine. The incorporation of excessive quantities of moisture, salt, or preservatives, or the addition of artificial colouring matter, are, however, the more usual forms of adulteration. The following points are important in the chemical examination of butter:

Method of Sampling

When butter is obtained for chemical examination, at least ¾ lb. should be purchased, which sample should be representative of the consignment. In the case of butter packed in tubs or boxes, the sample should be obtained by means of a trier inserted in a diagonal direction. Butter packed in wrapped blocks should be dealt with in yet another manner, as follows: If the examination is routine, three ¼-lb. blocks of one consignment should be purchased, but if the sample is purchased for chemical analysis under the Food and Drugs Act, 1938, a ¾-lb. or 1-lb. block should be obtained. If the butter is sold loose, a similar quantity should be purchased over the counter, duly wrapped. Official samples should be divided into three portions, one of which is handed to the retailer, one is sent for analysis while the third is retained by the person taking the sample. All butter

samples should be packed into wide-mouthed, screw-topped glass jars, labelled with the necessary particulars, and transmitted direct to the laboratory, where they should be stored in a refrigerator until required for examination. Before the sample is examined, it should be softened at as low a temperature as possible, and then thoroughly mixed until a perfect homogeneous mass is obtained. The portions to be used for analytical purposes should be immediately weighed from the prepared sample.

Types of Examination

The examinations usually made are:

(1) Fat Percentage.
(2) Total Solids.
(3) Moisture Content.
(4) Salt Content.
(5) Presence of Preservatives.
(6) Addition of Colouring Matter.
(7) Methylene-blue Reductase Test.
(8) Resazurin Test.
(9) Phosphatase Test.

(1) **Fat Percentage.**—It is possible by means of the Gerber method to determine with reasonable accuracy the percentage of fat present in a sample of butter. Weigh 0·5 gram of butter into a weighing funnel and transfer into a Gerber butyrometer containing 10 mls. of sulphuric acid (s.g. 1·815) covered with 6 mls. of distilled water. The last traces of butter on the funnel are washed into the tube with a minimum of very hot water. One millilitre of amyl alcohol is added and the butyrometer filled to the shoulder with warm distilled water. The subsequent procedure is similar to that used to determine the percentage of butter-fat in cream, a similar formula being used (see page 100).

The *Roese-Gottlieb* method may also be used to determine the fat percentage of butter. One gram of butter is weighed into the extraction flask, and to this is added 8 mls. of hot distilled water. The subsequent procedure is similar to that used in determining the percentage of butter-fat in ice-cream (see page 56).

No standard of fat percentage has been laid down in this country, but in America, butter must contain not less than 80 per cent. of butter-fat.

(2) **Total Solids.**—The technique of the applicable test is very similar to that used for the estimation of total solids in ice-cream, set out on page 57. One gram of butter is weighed into a dish, but in this case no water is added. The subsequent procedure is unaltered.

(3) **Moisture Content.**—To determine the moisture content of butter, a metal dish and rod are weighed. Ten grams of butter are then weighed into the dish, which is carefully heated, the contents being constantly stirred. When the casein shows a brown tint, the dish is removed and allowed to cool. It is then weighed, the difference between the two weights multiplied by ten giving the percentage of moisture present in the butter. Butter of good quality does not usually contain more than 12 per cent. of moisture. Some foreign butters contain less than this, while factory butters may contain moisture up to the limit of 16 per cent. fixed by

Section 32 of the Food and Drugs Act, 1938. A similar standard is fixed in the United States of America.

(4) Salt Content.—If the fat contained in the residue left after the examination for moisture has been completed is burnt off, the final residue may be regarded as the salt content. The amount present is calculated by subtracting the difference in weights of the dish and the butter before and after processing, allowance being made for the natural salt content of 0·1 per cent. which butter contains. In Australia and South Africa, butter may not contain more than 4 per cent. of salt. Six per cent. is probably the highest quantity which would be tolerated by the palate.

(5) Presence of Preservatives.—The addition of any preservatives to butter is forbidden, exception being, however, made in the case of salt. Ten per cent. of salt is necessary if any preservative action is to be obtained, but, since this quantity would have a detrimental effect upon the taste of the product, much smaller quantities are generally used, while, in some instances, preservatives are also added. The test for *boric acid*, most often used for preserving purposes, is carried out as follows: Ten grams of the sample are mixed with 200 mls. of water, the mixture being warmed until the fat melts. The whole is thoroughly shaken and allowed to stand until the fat rises to the surface. The liquid is siphoned off into a measuring cylinder and the volume noted. It is then placed in a conical flask, a few drops of methyl-orange and dilute sulphuric acid being added until a pink colour is obtained. The solution is boiled for three minutes and then cooled in water. When the liquid is cold, a few drops of phenolphthalein solution, followed by a N/10 sodium hydroxide solution, is added until a faint pink colour becomes apparent. A solution of glycerine and N/10 sodium hydroxide is next added in a quantity equal to one-third of the total volume, until a permanent pink colour persists. The number of millilitres of N/10 sodium-hydroxide solution used after the addition of the glycerine, multiplied by 0·0062, gives the amount of boron compounds calculated as boric acid present in the 10 grams of butter used.

(6) Presence of Colouring Matter.—Artificial colouring matters, of which *annatto* is outstanding, are sometimes added to butter in order to improve its appearance. Such an addition is not regarded as an adulteration in this country. If the colour of the butter can be bleached with alcohol foreign colouring matters are undoubtedly present, as the natural colouring matter is not soluble in that substance. More precise laboratory tests are used for the detection of added colouring matters, but such are outside the scope of this volume. The laboratory test for annatto in butter is similar to that used to detect the presence of this colouring matter in ice-cream, as set out on page 58.

(7) Methylene-blue Reductase Test.—The normal technique required for making the methylene-blue test in the case of milk does not apply to cream. For this reason, steps were taken by Hodson in New Zealand to modify the test as a check on cream received for butter-making. The apparatus required consists of normal 6 in. by ¾ in. test tubes marked at 10 and 20 mls. capacity and methylene-blue solution. This is made up by dissolving 1 gram of Methylene Blue (B.D.H.) in 2,000 mls. of distilled or sterilised water. A working solution is prepared by diluting this stock

solution twenty times and a fresh dilution should be prepared every few days. The cream to be examined is well stirred and 10 mls. added to a tube. Ten millilitres of the working solution are added, the tube is inverted several times so that the contents are thoroughly mixed and then placed in a water-bath at 40·5° C. After one minute has elapsed the tube is examined at intervals of five minutes up to twenty minutes, and finally at thirty minutes.

As regards standards, Hodson suggests the following are suitable:

TABLE 11

Cold Weather		Hot Weather	
Colour discharged in :	Action required	Colour discharged in :	Action required
Under 10 minutes	Bad. Inspection necessary	Under 5 minutes	Bad. Inspection necessary
Under 20 minutes	Improvement required and daily tests to be made	Under 10 minutes	Improvement required and daily tests to be made
Over 30 minutes	Satisfactory	Over 20 minutes	Satisfactory

This test is reported to compare favourably, as regards results, with the plate count. In America, Macy has modified this test for use in the grading of sweet cream. The general procedure is similar to that for milk except that triple-strength methylene-blue solution is employed.

(8) **Resazurin Test.**—This test has been adapted as a means of checking the cream received at the factory but does not appear to be so satisfactory as the methods of applying the methylene-blue test set out above.

(9) **Phosphatase Test.**—This test has been successfully employed in determining whether or not butter has been manufactured from pasteurised cream. The water serum is separated from the butter and 1 ml. of this is added to 10 mls. of the buffer-substrate solution. The remainder of the procedure is similar to that for milk.

Whey Butter

Whey, which is a by-product of cheese-making, contains varying proportions of butter-fat, and the separation of this fat repays the trouble and expense incurred in obtaining it from the liquid. Whey butter is imported into this country in large quantities and is largely used by confectioners. The method of manufacture varies according to the quantity of whey to be dealt with.

On the few farms where cheese is regularly manufactured, the quantity of whey will seldom be sufficient to justify the installation of a separator for the reclamation of the fat. In such cases the whey from the cheese-making process is collected in a suitable vessel, generally constructed of stoneware or of slate. Such materials are essential, as the action of the acid contained in the whey will quickly destroy contact surfaces, the use

of copper vessels being thus productive of fermentation and consequent taints. It is usual to employ two large collecting vessels in order that one may be properly cleansed and sterilised while the other is in use. In many instances, a whey-collecting chamber is installed under the cheese-room floor.

In factories where large quantities of whey are obtainable, the cream or butter-fat is separated from the remainder of the liquid. Because of the small proportion of fat contained in the whey (seldom more than one-tenth of the butter-fat present in the milk prior to its manufacture into cheese), a separator bowl of different design from that used for the separation of cream from whole-milk is fitted to the separator. Alternatively, the cream screw in an ordinary separator may be set to yield the thickest possible cream. Immediate separation of the whey is essential if the appearance of any cheesy flavour is to be avoided   Mechanical separation ensures that all the cream contained in the whey will be recovered.

In small farm dairies, the whey is allowed to stand for twenty-four hours in order that the cream may rise to the surface, whence it is removed by skimming. The cream is then placed in an earthenware vessel provided with an outlet at the base, where it is mixed with four to five times its bulk of boiling water, the whole being again allowed to stand for twenty-four hours. This water, which is afterwards drained off, clarifies the fat, removes the curd, and prevents the development of any undesirable, cheesy flavours. The cream is poured into a ripening pan and a quantity of "starter" added. Each day's supply of whey is treated in a similar manner, the fresh cream being added to the bulk daily and thoroughly stirred. If the cream sours too quickly (this is quite possible, as the reclaimed cream is only churned at weekly intervals), salt should be added. The cream is finally mixed with water and is churned in the ordinary manner.

In the factory, the cream is usually pasteurised and is often mixed with sweet, separated milk, the whole being ripened by the addition of a suitable "starter."

Butter manufactured in this manner must be given a thorough washing. If this point receives attention, an article of good quality and flavour will be produced, cheesy flavour being entirely absent. Such butter is usually pale in colour, and for this reason, a small quantity of colouring matter is often added.

Dehydrated Butter

Owing to war conditions, the problems involved in transporting large quantities of butter from New Zealand to this country and the small shipping space available for the purpose caused investigations to be carried out in that country at the Dairy Research Institute into methods of extracting the dry butter-fat from butter and packing it into suitable containers so that it could be transported as ordinary cargo and not be subject to rapid deterioration. From small-scale experiments carried out prior to the War, it was known that while butter lost its natural characteristics during this process, its nutritive properties were preserved.

Unsalted butter, possessing a low moisture content is melted with steam and part of the serum and solids-not-fat are separated out by gravity in a separating cylinder and the fat is recovered from the serum by means of a small separator. The bulk of the liquid fat is passed to a pasteuriser where its temperature is raised and finally to a supply tank. From here,

it travels through two further separators fixed in series, the moisture content being reduced to between 1 and 2 per cent. The fat then passes to a dehydrator where all further moisture is removed, and this operation is followed by cooling with a rotary cooler, from which it passes to cans which are filled and sealed, ready for export.

Milk-blended Butter

This type of butter finds little sale in Great Britain at the present time. It is manufactured from imported butter into which an additional quantity of milk has been worked, after arrival in this country. Milk-blended butter must not contain more than 24 per cent. of water, and may only be designated by descriptions approved by the Ministry of Agriculture and Fisheries. The presence of such a large proportion of moisture seriously interferes with the keeping qualities of the article.

Purvis and Hodgson give the following typical analysis of milk-blended butter:

							Per cent.
Fat .							74·2
Curd							1·1
Salt .							2·6
Water							22·1
							100·0

Renovated Butter

Butter which has become unfit for human consumption is treated in many countries by a process which is said to render it suitable for such consumption. Such methods, however, were not practised in Great Britain until the War which has now ended, when shortage of butter rendered it essential that every possible step should be taken to conserve supplies. The process is briefly as follows. The fat is melted, the curd removed by sedimentation, and air is blown through the liquid to disperse any offensive odours which may be present. The whole is then emulsified by churning with milk and is subsequently worked and washed, as in ordinary butter manufacture.

Canned Butter

In Germany, as a further development of the Alfa continuous butter making process described on page 133, which is reported by the British Intelligence Objectives Sub-Committee, Professor Möhr has prepared a canned butter conserve which has a fat content of 80 per cent. Hot cream possessing this fat percentage obtained from the Alfa process at a temperature between 140° and 158° F. is filled directly into metal cans. These are sealed and stored at temperatures varying between 68° and 86° F. Cooling must be as rapid as possible down to 104° F., but should never go below 68° F. After twenty-four hours storage, the cans are placed in boiling water for two hours so that the cream in the centre of the cans reaches a temperature of 185° to 194° F. The cans are then re-cooled at the temperatures set out above and after a further twenty-four hours, are once more heated for two hours in boiling water and are then cooled. The conserve is now allowed to cool to any desired temperature, being converted into butter in 4 to 8 days at 50° F. or in 6 weeks at 68° F. If

the milk as delivered from the farms possesses poor keeping quality, the canned product is heated three times instead of twice. The cans employed must be of the highest quality. The product can be stored at low temperatures for lengthy periods, although a loss of original freshness is unavoidable.

Synthetic Butter

Butter has been produced from paraffin in Germany by a process discovered by Arthur Imhausen. The paraffin is first treated by oxydisation and is then heated to extract the fatty acids. A second distillation is given to the fatty acids and glycerin and carotene are added. One hundred tons of paraffin are said to give 80 tons of fatty acids from which, in turn, approximately 40 tons of butter can be produced. It is further claimed that this type of butter is the only variety which can be eaten by diabetics as it contains no acetone which is present in ordinary butter.

MARGARINE

Introductory

Margarine was first exhibited in the year 1869, at a Congress organised by Napoleon III in Paris. Later, during the siege of Paris, a French chemist, Mege-Mouries, developed this substitute for butter, which latter product was then unobtainable. He pressed out the stearine from the fat of bullocks and added a small quantity of vegetable oil, to remedy the deficiency in olein. This composition gave an almost identical reproduction of genuine butter, and in those days the substance was often termed "artificial butter." The type of margarine then manufactured was perfectly white in colour. Margarine has increased considerably in popularity, particularly during the course of the War of 1914-18, for reasons which will be too obvious to require explanation. Between the wars, the low price of butter and the comparatively high price of good-quality margarine, caused its sales for normal home consumption to be lower than was once the case. Its value has again been proved during the War which has just ended and it is likely that it will remain in great demand at least until rationing ends.

For many years after its introduction, *oleo margarine*, prepared from beef and other animal fat, increased in popularity to such an extent that the demand exceeded the supply. Oleo margarine is now manufactured by a refining process of fractional crystallisation and careful pressing of the fat. Animal fats, together with vegetable fats, which are often added, are churned with skimmed milk, whole-milk, or cream which has been previously pasteurised and ripened with an artificial culture. Modern methods of refining, plus the increase in scientific knowledge appertaining to the hydrogenation of oils, have enabled a large number of oils of vegetable origin to be used. (Hydrogenation is the treatment of oils with hydrogen in the presence of a catalyst, generally nickel. By this process, liquid oils are converted into solid fats, while soft fats are hardened.)

The process of modern margarine manufacture requires very careful chemical and physical control, as the melting-points, hardness, and texture of the blended fats must be carefully regulated if the final product is to possess the consistency of butter. The type of margarine now upon the

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market is prepared by churning melted and clarified animal or vegetable fats with skimmed milk, whole-milk, or cream. Beef and mutton fat or occasionally lard are the animal fats used, although deodorised and hardened whale oil is frequently employed. The vegetable fats used are cotton-seed, sesame, palm-kernel and coconut oils, which may or may not be hardened fats. Margarine manufactured from palm-kernel oil is liable to develop rancidity. By the addition of skimmed or separated milk, whole milk,
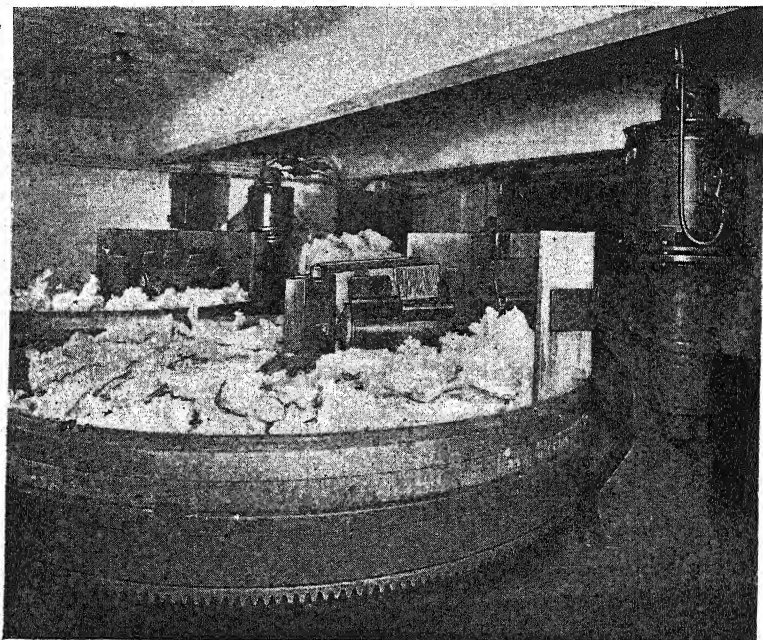
By courtesy of the General Electric Co., Ltd.

Fig. 49—Margarine Kneading Machine

or cream, the curd or casein found in margarine acquires a flavour somewhat similar to that of butter. The better grades of margarine always contain some portion of milk, either skimmed or whole, in their composition, together with a percentage of butter-fat. Margarines containing animal fat are considerably more nutritive than those composed solely of vegetable oils. Some poor grades of margarine contain large quantities of coconut or cotton-seed oils. Now that certain technical difficulties have been overcome, manufacturers are able to offer for sale vitamin-enriched margarines which contain similar proportions of vitamins A and D to those found in dairy butter. When margarine is carefully prepared from high-grade ingredients and coloured with pure annatto, it is not easy to distinguish the finished product from butter, either by taste or by smell.

Manufacture

The mixture of fats present in margarine is varied according to summer or winter temperatures. The fats are melted and blended thoroughly in jacketed pans, which are fitted with mechanical agitators. Fresh, cooled, separated milk is held in vats until the required degree of acidity develops,

by the addition of a controlled ripening culture. The actual process of churning the fats, milk, and other ingredients varies. The ingredients are usually fed from above into cylindrical churns, which are fitted with refrigerated jackets. The ingredients are thoroughly homogenised in the churn at the low temperature which obtains. The type of churn differs somewhat from the normal butter churn. It consists of a revolving core
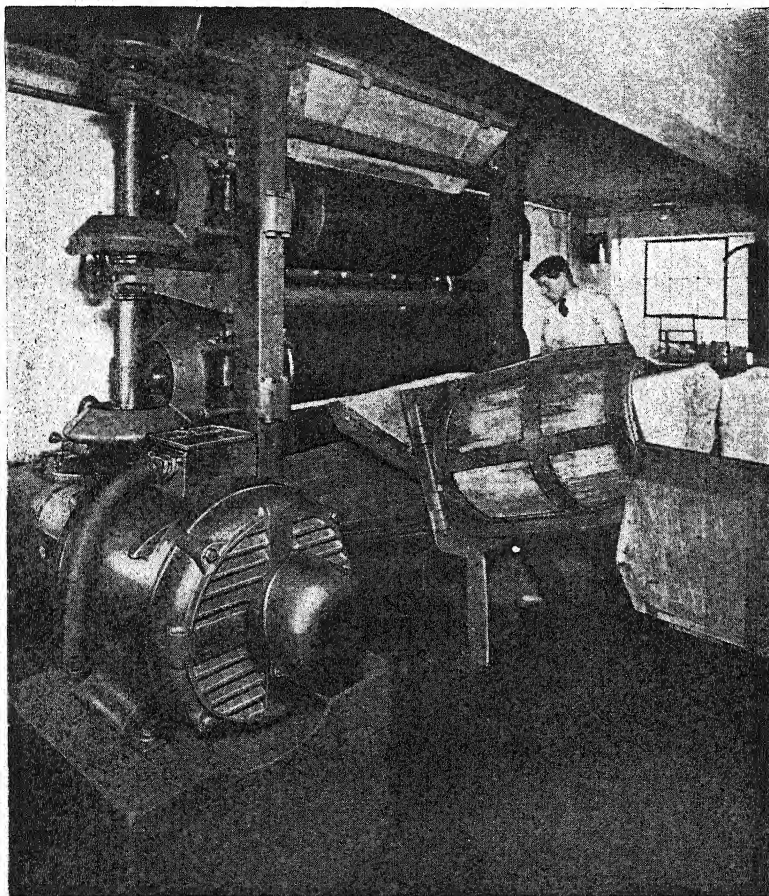
By courtesy of the General Electric Co., Ltd.

FIG. 50—Margarine Triple Roller Machine

which operates within the jacket, the mixed material being forced along certain definite channels until completely homogeneous mixture is delivered at the front of the churn and decanted into receiving vats. The product is then removed to cold storage, where it is hardened to the required consistency. The product is finally packed into boxes, or formed into rolls or pats as required.

Food Value

The food value of margarine varies. Drummond and Halliburton have reported that margarine manufactured from beef fats is as satisfactory

for the nutritive requirements of young rats as is butter. When composed of vegetable oils, margarine did not provide sufficient nutrition to enable the young animals to reach maturity (for further experiments conducted on school children, see page 123).

As regards *calorific value*, the Committee on Nutrition of the British Medical Association give the following figures, which may be taken as representative:

	Protein (grams)		Fat (grams)		Calories
1 lb. Butter	0·9	....	376·5	....	3,503
1 lb. Margarine	0·9	....	384·7	....	3,579

These figures show an advantage of 2·1 per cent. in favour of margarine. Its *digestibility* is in the neighbourhood of 96 to 97 per cent., while the *taste and flavour* of modern margarine are, to the average person, indistinguishable from butter. Its *vitamin potency* is high, vitamins A and D being added during manufacture. Further the vitamin standard is maintained all the year round, while in butter this can be extremely variable according to the season of the year.
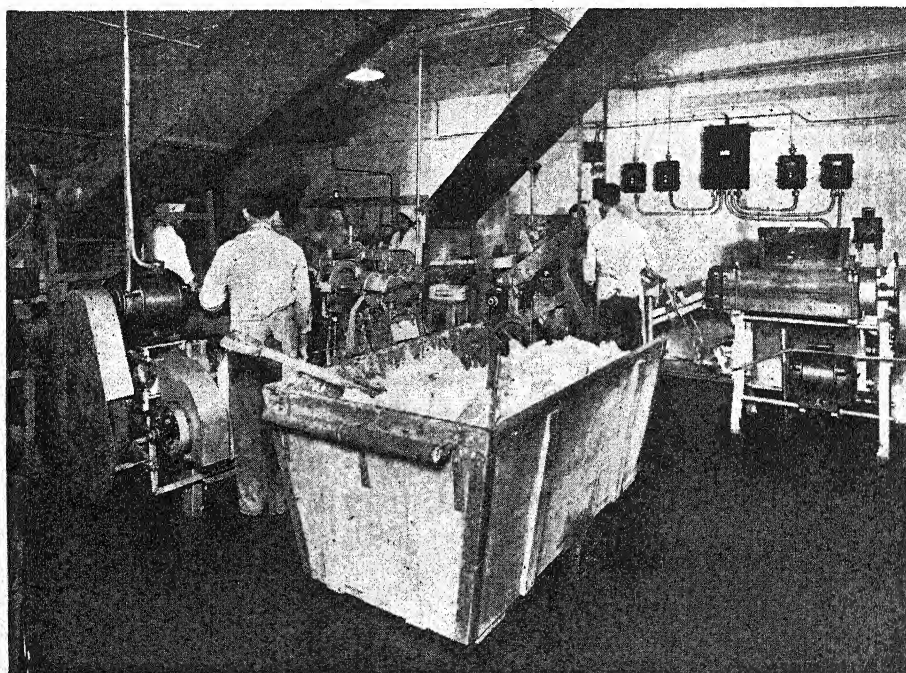
By courtesy of the General Electric Co., Ltd.

FIG. 51—Margarine Packing Machinery

There can be little doubt that, with the high-grade types of margarine now upon the market, the food value of the product has been considerably enhanced. Whether the demand for the article as an integral constituent of everyday diets will continue, in face of the competition from cheap-price, imported butter, is a matter of conjecture which need not be discussed here. It will be sufficient to state that margarine possesses a

definite food value, and that its use for culinary and similar purposes is clearly of value.

Composition

The following table, compiled by Clowes and Coleman, compares the average composition of butter and margarine:

	Salt Butter. Per cent.		Margarine. Per cent.
Fat	84·3	. . . .	83·2
Water	13·5	. . . .	14·6
Curd	0·3	. . . .	1·8
Salt	1·9	. . . .	0·4
	100·0	. . . .	100·0

The quantity of butter-fat in margarine is limited to 10 per cent. of the whole, while the proportion of moisture present is restricted to 16 per cent. In Germany, manufacturers of margarine are required to add 10 per cent. of sesame oil to the product, in order that it may readily be identified. A similar proposal was put forward for this country by the Departmental Committee on Butter Regulations. Repeated suggestions have been made by those interested in the butter trade to the effect that the addition of artificial colouring to margarine should be prohibited, or that, as an alternative, some distinctive colouring matter should be added. Up to the present, such suggestions have not been adopted, although they are practised in other countries. Thus, the addition of colouring matter to margarine is prohibited in many parts of the world, while, in Australia, a distinct pink colour must be imparted by the addition of alkanet root. New South Wales requires the addition of a specified proportion of sesame oil, while, in Queensland, arrowroot starch must be added.

Margarine must always be prominently labelled, particulars of such labelling being set out on page 175.

LEGISLATIVE CONTROL

The law dealing with the production and sale of butter, milk-blended butter, and margarine is comparatively simple. A summary of the Acts and Orders which apply, together with the appropriated Sections or Articles, is set out below.

Act or Order	Section or Article
Public Health (Preservatives, etc., in Food) Regulations, 1925	4, 6, 11
Factories Act, 1937	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 41, 42, 43, 44, 45
Public Health (Imported Food) Regulations, 1937	6, 7, 8, 9
Food and Drugs Act, 1938	1, 2, 3, 13, 17, 18, 32, 33, 34, 35, 36, 40, 41, 42, 68, 69, 70, 73
Defence (General) Regulations, 1939	60CAA
The Margarine and Cooking Fats (Requisition) Order, 1940	Whole Order
The Margarine (Pre-packing) Order, 1940	Whole Order
Butter (Control and Maximum Prices) Order, 1943	Whole Order

All superfluous matter has been omitted from the following excerpts, and only such parts as apply directly to the manufacture, storage, or sale of butter, etc., have been indicated.

Public Health (Preservatives, etc., in Food) Regulations, 1925

Articles 4, 6 and 11 of these Regulations, which deal with the prohibition of preservatives in home-produced and imported foods, have already been dealt with on pages 60 and 104.

Factories Act, 1937

Food premises coming within the terms of this Act are not governed by the conditions laid down by Section 13 of the Food and Drugs Act, 1938. The relevant Sections, the terms of which apply to the sanitary control of all food preparing factories, have already been detailed on page 62.

Public Health (Imported Food) Regulations, 1937

Prohibit Import of Unsound or Unfit Food.—Article 6. Provides that no article of food which is unfit for human consumption, or in which any such article is compounded, shall be imported.

Food may be Examined by M.O.H.—Article 7. Provides that a Medical Officer of Health may inspect any food while aboard ship or after landing. Facilities must be afforded for this purpose.

Taking of Samples.—Article 8. Samples may be taken from any consignment of food by the Medical Officer of Health for examination.

Seizure and Condemnation of Unfit Food.—Article 9. Any food found to be diseased, or unsound or unfit or unwholesome, may be seized. The subsequent procedure is prescribed.

Food and Drugs Act, 1938

Sections 1, 2, 3, 13, 17, 18, 68, 69 and 70 together with the definition of "food" have received attention on pages 64 to 67. The definitions of "dairy" and "dairyman" will be found on page 108. The Sections which govern the special control of butter, margarine, and milk-blended butter are detailed below.

Definitions: "Butter" means the substance usually known as butter, made exclusively from milk with or without salt or other preservative, and with or without the addition of colouring matter.

"Margarine" means any food, whether mixed with butter or not, which resembles butter and is not milk-blended butter.

"Milk-blended Butter" means any mixture produced by mixing or blending butter with milk.

Limit of Water in Butter, etc.—Section 32. (1) A person who sells, or offers or exposes for sale, or has in his possession for the purposes of sale—

(a) any butter which contains more than sixteen per cent. of water; or

(b) any margarine which contains more than sixteen per cent. of water, or the fat of which contains more than ten per cent. of fat derived from milk; or

(c) any milk-blended butter which contains more than twenty-four per cent. of water,

shall be guilty of an offence.

(2) Any label or advertisement which states or suggests that margarine with which it is given, or to which it relates, contains butter shall state the percentage of butter which it contains.

Provided that no offence shall be deemed to have been committed under this subsection, if the figure stated as the percentage of butter does not differ by more than two from the actual percentage.

A person who gives with any margarine sold by him a label, whether attached to or printed on the wrapper or container or not, which does not comply with the requirements of this subsection, or who publishes, or is a party to the publication of, an advertisement which does not comply therewith, shall be guilty of an offence.

Requirements as to Labelling, etc.—Section 33. (1) A person who sells, or forwards by any public conveyance, any margarine . . . or milk-blended butter, shall sell or consign it as margarine . . . or, in the case of milk-blended butter, under an approved name.

(2) Every person dealing in margarine, whether wholesale or by retail, and whether as manufacturer, importer, consignor, consignee, commission agent, or otherwise, shall conform to such of the following regulations as may be applicable:—

(*a*) every container containing margarine shall have the word "MAR-GARINE" branded or durably marked on the bottom and sides and also, if it be closed, on the top thereof, in block letters not less than three-quarters of an inch long, the brand or mark being on the container itself and not only on a label, ticket, or other thing attached thereto;

(*b*) there shall be attached to every parcel of margarine exposed for sale by retail, in such manner as to be clearly visible to the purchaser, a label marked "MARGARINE" in printed block letters not less than one and a half inches long;

(*c*) margarine when sold by retail, save in a container branded or durably marked as aforesaid, shall be delivered to the purchaser in a paper wrapper, with the word "MARGARINE" printed on the outside of the wrapper, or, if more wrappers than one are used, on the outside of the outer wrapper, in block letters not less than half an inch long and distinctly legible, and the outside of that wrapper shall bear no other printed matter, except such matter as may be required by or under any other enactment;

Paragraph (*c*) above has been amended by Defence Regulation 60CAA (see page 177);

(*d*) margarine shall not be described on, or on a label enclosed within, any wrapper enclosing or container containing it, or on any label attached to a parcel thereof, or in any advertisement or invoice thereof, by any name other than "MARGARINE" or a name combining the word "MARGARINE" with an approved fancy or other descriptive name printed in type not larger than, and in the same colour as, the letters of the word "MARGARINE."

(4) The requirements of paragraphs (*a*), (*b*), and (*c*) of the last preceding subsection shall apply in relation to milk-blended butter and to persons dealing therein with the substitution of an approved name for the word "MARGARINE", but on the outside of the wrapper referred to in the said paragraph (*c*) there shall, in addition to the approved name, be printed in an approved manner an approved description of the article, setting out the percentage of water contained therein.

(5) A person who contravenes any of the foregoing provisions of this Section is guilty of an offence.

(6) Any substance resembling butter . . . which is exposed for sale and is not marked in the manner which margarine, milk-blended butter . . . is required by this Section to be marked shall be presumed to be exposed for sale as butter . . .

(7) In this Section the expression "approved" means approved by the Minister of Agriculture and Fisheries, who, in approving for the purposes of this Section names to be used in relation to margarine or milk-blended butter, shall not approve any name which refers to, or is suggestive of, butter or anything connected with the dairy interest.

Registration of Factories, etc.—Section 34. (1) No premises shall be used —

(*a*) as a factory of margarine . . . or milk-blended butter;

(*b*) for carrying on the business of a wholesale dealer in margarine . . . or milk-blended butter; or

(*c*) as a butter factory, that is to say, a place at which by way of trade butter is blended, reworked, or subjected to any other treatment, but not so as to cease to be butter,

unless they are registered by the Food and Drugs Authority for the purpose in question.

(2) Subject to the provisions of the next succeeding subsection, a Food and Drugs Authority shall, on the application of the occupier of, or of a person proposing to occupy, any premises, register those premises for the purposes of this Section.

(3) Premises shall not be registered or used as a butter factory if they form part of, or communicate otherwise than by a highway with, any other premises which are required to be registered under paragraph (*a*) or paragraph (*b*) of subsection (1) of this Section.

(4) A person who on premises not registered for the purpose in question carries on any such manufacture, business, or trade as is mentioned in subsection (1) of this Section, or who uses any premises as a butter factory in contravention of the provisions of the last preceding subsection, shall be guilty of an offence.

(5) Upon any change in the occupation of premises registered under this Section, the incoming occupier shall, if he intends to use them for the purpose for which they are registered, forthwith give notice of the change to the Food and Drugs Authority, who shall thereupon make any necessary alteration in their register. Penalty provided for failure to give such notice.

(6) A Food and Drugs Authority shall forthwith give notice to the Minister of Agriculture and Fisheries of any registration of premises under this Section, of any change in the occupation of registered premises and of the deletion from the register of any premises which have ceased to be used for the purpose for which they were registered.

Register of Consignments to be kept.—Section 35. (1) Every occupier of a factory of margarine . . . or milk-blended butter, and every wholesale dealer in any such substance, shall keep a register showing the quantity and destination of each consignment of margarine . . . or milk-blended butter, as the case may be, sent out from his factory or place of business, and the register shall be open to inspection by any officer of the Minister of Agriculture and Fisheries.

(2) If any such occupier or dealer—

(*a*) fails to keep such register posted up to date; or

(*b*) wilfully makes in the register an entry which is false in any particular, or wilfully omits to enter in the register any particular which should be entered; or

(*c*) refuses to produce the register when required to do so by an officer of the Minister of Agriculture and Fisheries,

he shall be guilty of an offence.

Prohibition of Adulterants in Butter Factories.—Section 36. If any substance intended to be used for the adulteration of butter is found in a butter factory, the occupier of the factory shall be guilty of an offence, and, if any oil or fat capable of being so used is found in such a factory, it shall be presumed to be intended to be so used, unless the contrary is proved.

Restrictions on Importation.—Section 40. Makes it an offence to import

(*a*) any margarine . . . except in containers conspicuously labelled "MARGARINE". . .

(*b*) any milk-blended butter, except in containers conspicuously marked with a name approved for the purpose by the Minister of Agriculture and Fisheries, not being a name which refers to, or is suggestive of, butter or anything connected with the dairy interest.

(*c*) any butter, margarine or milk-blended butter the sale of which would be an offence under subsection (1) of section thirty-two of this Act.

Section 41, which deals with sampling of imported foods, and Section 42, which deals with penalties, are set out on page 110.

Powers of Sampling.—Section 68. (3) A sampling officer may take samples of—

(a) any butter or . . . , or substances resembling butter or . . . , exposed for sale and not marked in the manner in which margarine, milk-blended butter or . . . is required to be marked under this Act;

Power of Entry.—Section 73 (1) Gives power of entry to any officer of the Minister of Agriculture and Fisheries on producing his written authority to enter at all reasonable times any premises registered under Section 34 of this Act and to inspect any process of manufacture, blending, reworking, or treatment carried out therein and to take samples of any butter, margarine . . . or milk-blended butter or any substance capable of being used in the manufacture, treatment, or adulteration of any of those articles.

(2) If the Minister of Agriculture and Fisheries has reason to believe—

(a) that any process of manufacture, blending, reworking, or treatment, or any wholesale dealing, being a process or dealing which under this Act may not be carried on except on registered premises, is being carried on on any premises not registered for the purpose in question; or

(b) that on any premises butter is by way of trade either made or stored, and that for the purposes of this Act inspection is desirable,

he may specially authorise any of his officers to enter the premises, and in that case the officer shall have the like powers of entry, inspection, and sampling as if the premises were registered.

Defence (General) Regulations, 1939. 60 CAA

This Regulation enacts the terms of the Margarine (Addition of Borax) Order, 1940, and states that except under the authority of the Minister of Food or for export or for ships' stores, the addition of borax to any margarine is prohibited by the terms of the Order. The addition of borax, including boric acid and borates, is legalised if the Minister agrees. The Order has been promulgated as an emergency measure and the maximum amount permitted under licence was 0·25 per cent. This Regulation continues the limit previously fixed by the Order, and some amendment appears to be likely in order to make it clear that boric acid and borates may be used in addition to borax.

This Regulation also amends Section 33 of the Food and Drugs Act, 1938, as regards the labelling of margarine as follows:

(a) The words "in block letters not less than ½ inch long" shall be substituted by "in block letters of a type at least as large as that of any other letters printed on the outside of the wrapper."

(b) The use of the words "and the outside of that wrapper shall bear no other printed matter, except such matter as may be required by or under any enactment" is suspended until the Regulation is repealed.

The Margarine and Cooking Fats (Requisition) Order, 1940

This Order, amongst other things, prohibits the manufacture and wholesale sale of margarine except under directions or licence from the Minister of Food.

The Margarine (Pre-packing) Order, 1940

The Order lays down that no margarine may be pre-packed, ready for retail sale, except by licence.

The Butter (Control and Maximum Prices) Order, 1943

Definitions: "Butter" includes whey butter.

"Farm Butter" means butter produced by a farmer on his premises from milk produced by him.

This Order prohibits, except under the licence:

(1) The manufacture of butter for sale, other than farm butter.
(2) The pre-packing of butter (does not apply to Northern Ireland).
(3) Buying or selling of butter if this is situated outside the United Kingdom.

All butter is to be marked with the words "NATIONAL BUTTER" in letters at least half an inch high and it must be sold in marked wrappers. All wholesalers must keep complete records of purchases, sales and stocks, while the production of an analyst's or Government Chemist's certificate of examination is to be taken as sufficient evidence unless the court or other party requires the analyst to be called as a witness.

CHAPTER IV

CHEESE

Introductory

CHEESE, in any one of its many forms, is an article of diet which has attained very considerable and increasing popularity during the last few decades. Its origin dates back many centuries, and it is probable that a desire to retain for future use the many valuable constituents of milk in a permanent and saleable form caused cheese to be primarily manufactured. The first method of preservation was to allow milk to sour naturally, the whey being drained off and the resulting curd dried and salted. The manufacture of cheese in this manner is still carried out in the East. It was later discovered that the curd would keep without drying and that, if treated in a suitable fashion, i.e. allowed to ripen, it would possess certain additional valuable properties. Thus, the science of cheese manufacture became the means of producing a palatable food as well as a medium for preservation.

Cheesemaking may be described as the most primitive form of dairying for, until the advent of railways this was the only way in which milk, or its equivalent, could be marketed on a large scale. Although most parts of the country eventually came within close proximity to the railway system, the liquid milk trade from country to town did not develop for many years, each large centre of population obtaining milk from the country districts adjacent to it. Eventually, as more liquid milk was required, the original cheese-making farms ceased manufacture and to-day the production of cheese is centred almost exclusively in creameries and factories. Until the year 1850, all cheese was manufactured in farm-houses, but from that date onwards the modern factory system was developed, first in America and later in this country where the first cheese factory was opened at Derby in 1871. Since the War of 1914–18, farm-house cheese-making has rapidly declined.

The perfect co-operation of bacteria, yeasts, and moulds is essential if good quality cheese is to be manufactured. In the first stage the milk must be ripened, this being accomplished by lactic-acid organisms of various types, which are either allowed to develop naturally in the milk or are added in the form of a pure artificial culture. These organisms prepare the milk for clotting, while, in the curd, the acids which they form assist the ripening process and regulate the growth of other organisms. In the later stages of manufacture, various specific bacteria and moulds are made use of to complete the process begun by the lactic-acid organisms.

Authorities have stated that more than five hundred varieties of cheese are manufactured in various countries, while new types are continually being evolved. These cheeses are prepared in varying ways and ripened by different types of organisms. Commercially, however, only a small proportion of the numerous varieties are considered to be distinct types, possessing flavours and characteristics peculiarly their own. In many instances, the differences are so slight as to be entirely negligible.

The production of cheese in Great Britain probably does not exceed

100,000 tons per annum, and manufacture has certainly not kept pace with demand, although the cheese-eating habit has been retarded during the War by the restricted supply. When rationing ceases, vigorous publicity will be necessary to build the per capita consumption up to pre-war levels. The principal variety of cheese consumed in this country is the Cheddar type, this being manufactured in considerable quantities. Vast quantities of cheese are imported annually, principally from New Zealand, Canada, and the Continent. Certain types of cheese must of necessity be imported, as they are peculiar to individual countries. Such types have enjoyed increased popularity, to the disadvantage of our national varieties.

The greatest quantity of cheese manufactured in the British Isles is produced during the summer months, when the farmers possess an excess of surplus milk. The demand for liquid milk which can be sold at a guaranteed price, together with the provision of speedy and efficient means of transport to the large centres of population, has induced many farmers who originally used their milk for the manufacture of cheese to enter the liquid-milk market and such persons have practically ceased to manufacture this foodstuff.

From the farmers' point of view, cheese-making is more profitable than the manufacture of butter. A good milk possessing a 3·5 per cent. butter-fat content will only yield 1 lb. of butter for each $2\frac{1}{2}$ gallons of milk; whereas a similar quantity of milk of the same quality will yield $2\frac{1}{2}$ lb. of cheese, and probably even more if the cheese is of the soft variety.

Composition

The composition of cheese varies considerably. No standard of composition has been fixed in this country, but in the United States of America and in Canada, the following standards are in force:

United States of America

(1) Plain cheese (Cheddar type), 50 per cent. milk-fat in dry substance. Not more than 39 per cent. water. Fat content of many special cheeses is limited.

(2) Cream cheese, 65 per cent. milk-fat.

Canada

(1) Full-milk cheese, 45 per cent. milk-fat in dry substance.

(2) If fat content is below 45 per cent. the article must be labelled as skimmed-milk cheese.

Cheese contains fat, casein, mineral salts, and water, the percentages of each constituent varying according to the variety of cheese in question. Table 12 sets out the analyses of several of the better-known varieties of cheese.

The absence in this country of any compulsory standard enables cheese to be sold which may contain very little fat, and which has been manufactured from either whole or skimmed milk without any appropriate notification being made to the purchaser. The error of such a procedure is too obvious to require more than mere mention. Cheese should not contain any fat other than that derived from milk. Certain "margarine cheeses" have been placed upon the market, consisting mainly of various animal and vegetable fats, these spurious products being imitations of the real article. It is an offence under the Food and Drugs Act, 1938, to sell such cheese without the proper, prescribed labelling.

TABLE 12

Type of Cheese	Fat	Water	Casein, etc.	Ash
Cheddar . .	33·70	34·20	27·60	3·80
Stilton . . .	45·80	21·20	26·30	2·90
Cheshire . .	35·30	31·60	26·50	4·40
American . .	33·90	29·80	30·30	3·70
Swiss . . .	30·61	33·81	29·22	4·16
Gruyère . .	28·60	28·20	31·30	4·70
Brie . .	27·50	50·04	18·24	4·12
Gorgonzola . .	26·70	33·90	25·80	4·60
Dutch . . .	22·50	37·60	29·10	6·50
Gloucester . .	28·10	37·40	28·30	4·60
Camembert . .	27·40	49·00	21·00	2·60
Roquefort . .	30·30	29·60	28·30	6·70
Bondon . .	24·40	39·50	9·40	0·70
Gervais . .	35·45	40·50	21·30	2·75
Limburger . .	29·82	35·64	28·53	5·98
Neufchatel . .	18·17	59·22	21·30	2·43
Parmesan . .	22·65	27·93	41·94	6·07
Cream . . .	67·15	23·99	9·17	0·69

Food Value

Milk, which is the parent of cheese, contains fats, salts, protein, and sugar, together with a supply of each of the known vitamins, being particularly rich in vitamins A and B_2. In the case of cheese, however, the child is much more nutritious than the parent, although it should be stated that cheese contains only traces of sugar, the bulk of which passes out in the whey. In other words, cheese may be described as milk in concentrated form. This will be more readily understood when it is remembered that it takes approximately 1 gallon of milk, i.e. 10 lb., to produce 1 lb. of cheese. The latter is especially rich in fat and protein, and, if kept or ripened for a period, is exceptionally digestible. For this reason, cheese should preferably be three months old before it is consumed. Cheese is an exceedingly concentrated and economical food which is easily digested, over 90 per cent. of the cheese assimilated by the body being changed into body tissue or energy. It has been stated by Kenwood that 1 lb. of the product contains a food value equivalent to $2\frac{1}{2}$ lb. of meat. Protein is one of the most expensive parts of our daily diet and 1 lb. of cheese is equivalent in protein to approximately 2 lb. of fowl or pork. There is little waste, while it contains no bone and only half the moisture of meat or eggs. Furthermore, its comparatively reasonable price places it within reach of all sections of the community, a fact which is fortunately beginning to receive the attention which it merits. Cheese can be used in innumerable ways and it is extremely palatable. It does not need to be refrigerated in order to keep it and it may be used in its natural state, irrespective of weather conditions.

Cheese is manufactured either from whole or skimmed milk or from cream, and it will be obvious that the food value of skimmed-milk cheese is not comparable with that of cheese manufactured from whole-milk or cream. Notwithstanding the lower food value, there is nothing to distinguish whole- from skimmed-milk cheeses when exhibited for sale. Many tons

of foreign, skimmed-milk cheeses were imported into this country prior to the War and were sold at prices which undercut home-produced cheeses, to the detriment of many British farmers and cheese manufacturers. One of the most urgent reforms required is the fixing of a standard of fat content for all cheeses, which should be properly labelled as to the quality of their primary constituent.

Outbreaks of Disease due to Cheese

The principal outbreaks of disease due to the consumption of infected cheese have been cases of food poisoning, although epidemics due to other diseases are reported from the United States of America. In the Special Report Series of the Medical Research Council, No. 92—1925, Savage and Bruce White report that, in a study of 100 recent outbreaks of disease caused by infected foodstuffs, eight were due to cheese. Cheese is associated with a distinct type of poisoning of doubtful ætiology. Cheese poisoning was formerly attributed to a toxic substance known as *tyro-toxicon*, but research has shown that, so far as cases of cheese poisoning are concerned, this toxic agent is not responsible. It is probable that several toxins are involved and that some are products of members of the Gaertner group, as yet unclassified. It may be, indeed, that the toxins are well-known members of this group which have been so altered by the enzymes or ferments in the cheese as to be unrecognisable. The cheeses affected rarely exhibit any physical abnormalities.

In 1922, Canadian Cheddar cheese gave rise to food poisoning, but no causative organisms were isolated. There was also one outbreak in the same year due to the consumption of Wensleydale cheese. Agglutination tests for the presence of the Salmonella group gave positive results, while *tyro-toxicon* was not found in any of the cheese. At Harrogate in 1923, twelve persons were attacked by food poisoning, the severity of the symptoms appearing to correspond to the quantity of cheese consumed. In the portion of cheese examined, no *tyro-toxicon* was found, but the sera of two patients agglutinated two separate Salmonella strains. During 1933, two outbreaks of food poisoning due to cheese were reported, thirty persons being affected. The outbreaks were ascribed to imported Cheddar cheese. Clinically, the cases were of the toxin type, but bacteriological examination gave negative results.

Typhoid fever epidemics have been reported from America following the consumption of infected cheese. One of these, which occurred in 1923 and involved 51 cases with 4 deaths, was traced to cheese made on a farm at which a typhoid "carrier" was employed. The cheese in question was about one month old when eaten. An extensive outbreak occurred in Canada in 1932, involving 627 persons, of whom 57 died. The manufacturers of the infecting cheese all used milk from farms on which there had been or still were cases of typhoid fever. The cheese was consumed in a partially-ripened state.

Cases of *staphylococcal poisoning* due to the consumption of cheese infected with *Staphylococcus albus* and *Staphylococcus aureus* have been reported from America while cases of *botulism* due to cheese from which *Clostridium botulinium* (Type B) was isolated, have also occurred.

Manufacturing Premises

Premises intended to be used for cheese-making should be carefully planned and constructed. The accommodation usually required consists of:

(1) Milk-treatment Room.
(2) Cheese-making Room.
(3) Ripening Room.
(4) Sterilising Room.

The *aspect* of the premises is important. A northern light is desirable, as, if direct sunlight obtains entrance to the various rooms, the temperature, which is so important in cheese-making, will be difficult to control. The building or buildings should be situated as far as possible from any likely sources of contamination.

As previously indicated, one of the essentials to the manufacture of good cheese of uniform quality is the maintenance of an even temperature. The *roof* should therefore be constructed of tiles in preference to slates, which are more subject to changes in temperature. Thatched roofs are satisfactory, but relatively scarce. *Lime-washing* the tiled roof is a useful method of maintaining an equable temperature within the building. Ample *lighting*, both *natural* and *artificial*, together with adequate *ventilation*, are, of course, essential. As a means of improving ventilation, all *windows* should be fitted with fine-meshed wire gauze, which will allow the free circulation of air, while preventing the entrance of dust and insects.

The *floor* should be constructed of some hard, impervious material, such as concrete. Red tiles laid in cement upon a concrete foundation are ideal for this purpose, being both impervious to moisture and cleanly in appearance. The floors should be sloped to surface gutters or channels, which, in turn, should be carried out through the walls to discharge over trapped gullies duly connected to an adequate drainage system. The *walls* should possess a smooth internal surface. Cement rendering is satisfactory for this purpose, although glazed bricks or tiles, while more costly, impart a much more desirable finish. If the walls are cement-rendered, the cement should be carried to a height of at least 5 feet from the floor-level, in order to facilitate cleansing. The portion of the walls above the rendering should be periodically limewashed. The *ceilings* should preferably be plastered and limewashed.

An adequate supply of *hot and cold water* is essential. A *boiler* of sufficient size should be provided for steam raising and water heating. A *separate* boiler-house is essential, to ensure that any dust or heat from the boiler does not obtain entrance to the premises. Where cheese is manufactured throughout the year, some form of *heating* is necessary in order to maintain an equable temperature. A low-pressure heating system with a separate boiler should be installed for this purpose.

The *size* of the rooms will vary according to the quantity and varieties of cheese manufactured. Sufficient space should be provided in the *milk-treatment room* for coolers and storage vats. The *cheese-making room* will contain cheese vats, curd mills, and the cheese presses, although the provision of a separate pressing room is to be preferred. Sinks should be provided in each room in order that the employees may be able to wash their hands, while an adequate supply of clean towels and soap should also be provided. The *ripening room* should be well ventilated with adequately controlled heating arrangements. *Thermometers* should be fitted in all rooms.

The *utensils* are important.   Although good-quality cheese may occasionally be manufactured with makeshift apparatus, it is essential that modern utensils of satisfactory design should be obtained if a product of uniform quality is to be anticipated.   Such utensils facilitate the labour of manufacture and also render the work of cleansing and sterilisation more easy.

Personnel

The persons employed in manufacture should be sufficiently skilful to carry out their work without constant supervision.   Control of acidity, moisture, and temperature are important in cheese-making, and employees should therefore be intelligent and capable of acting upon their own initiative.

Workers should be possessed of cleanly habits and be in satisfactory bodily health.   It should never be forgotten that cleanly, healthy workers are just as important in the manufacture of cheese as in the manufacture of other foodstuffs.   It is advisable that all employees should be medically examined on commencing work, and that they should undergo a periodical medical examination.

Cleansing and Sterilisation

All utensils used in the production of cheese should be efficiently cleansed and sterilised after use, and should be stored in a clean place after such treatment.   For this purpose, ample supplies of *hot and cold water* and *steam* should always be available.   Chlorine solutions of suitable strength may be used if desired for sterilisation purposes.   It must again be emphasised that there is no substitute for steam or chlorine solutions as a means of sterilisation.   When it is remembered that cheese-making depends upon the growth of desired types of moulds and bacteria, and that the growth of unwanted types following the lack of efficient sterilisation may cause incalculable harm both from a public health and from a commercial standpoint, the need for efficiency in this direction will be obvious.

Cheese-making Process

The process of cheese-making varies in numerous details, in accordance with the variety of cheese manufactured.   Such details will be discussed later in the chapter, but the general process applicable to all types may be divided into certain well-defined stages, as follows:

(1) Milk Supply.
(2) Ripening the Milk.
(3) Renneting.
(4) Curd Preparation.
(5) Pressing and Ripening.

The object aimed at in cheese-making is to coagulate the milk solids in such a manner as will enable them to be compressed, stored, and transported with ease, while retaining all the nutritive value of the original milk.

In preparation, milk is clotted by the action of rennet, by natural souring, or by the addition of pure cultures of lactic-acid organisms.   The curd forms, is removed from the cheese vat, and pressed, in order to remove from it all traces of the whey which it contains.   Heavy pressure is used for hard cheeses, while in many instances soft cheeses are ripened in an unpressed state.

(1) **Milk Supply.**—It has been recognised for some considerable time that certain districts produce the best cheese of a given type, and while the purity of the milk used for butter-making is definitely important, the cleanliness of the milk to be used for cheese-making is an even more vital factor. An entire batch of cheese may be ruined by the presence of unwanted organisms which may produce gas or other undesirable fermentations. Milk which is to be used for cheese-making should be produced under hygienic conditions from healthy cows. The treatment and storage of the milk prior to use are also important. The milk should be cooled and suitably stored until required for use, as, if the temperature of the liquid is allowed to rise, any organisms contained therein will rapidly multiply. The butter-maker can always pasteurise his milk to eliminate unwanted organisms before the "starter" is added, and in many instances, pasteurisation of the milk is now looked upon as of primary importance. Pasteurised milk cheese ripens more slowly and develops a milder flavour but possesses a longer keeping quality and provides a more uniform product. The short-time process is preferable for this purpose as the low-temperature method usually results in a soft curd and crumbly cheese. The popular method is to employ a plate heat-exchanger at temperatures between 165° and 170° F. for a period of fifteen seconds. The yield of cheese is generally increased by pasteurisation, due, in all probability, to the coagulation of the albumin, the precipitation of the calcium salts and the greater humidity of the cheese. Another advantage obtained from processing is that the whey contains no disease-producing organisms, and can be used for animal feeding without hesitation, while organisms of animal disease will be absent from cheeses manufactured from pasteurised milk. Certain types of cheese, however, must of necessity be manufactured from fresh, raw milk, the cheese-maker being therefore unable to control the bacterial content of his milk to the same desirable extent.

All batches of milk arriving at cheese factories are tested by means of the resazurin and fermentation tests (see pages 59 and 253) before use. The *Wisconsin curd test* may also be employed, to ensure the existence of suitable cleanliness for cheese-making. A clean, sterile pint glass jar is used for each sample, the jars being filled to two-thirds of their capacity. The samples are labelled in accordance with the different batches of milk. The jars are then heated in a water-bath until the milk temperature reaches 98° F. Ten drops of rennet extract are next added to each sample and mixed with the milk by gently rotating the jars. The milk quickly curdles and the curd is allowed to stand until it becomes firm. It is then cut into small pieces which are stirred at half-hourly intervals. When the mass becomes really firm, the whey is poured off, the curd being left at the bottoms of the jars. The curd is allowed to stand for a further period in order to drain off any whey still remaining. The curd becomes still firmer and is allowed to remain and ferment in the sample jars for a further six to twelve hours, at 98° F. At this temperature, the production of gas will be noticeable. The pieces of curd should be sound and free from gas bubbles, while the odour and taste should not be unpleasant. If any of the batches of milk contain large numbers of *Bacillus coli*, the curd from such milk will possess an unpleasant flavour and gas bubbles will be noticeable. Putrefactive bacteria present in the milk will cause the curd to possess a very unpleasant odour. Samples of milk which would be unsuitable for

the manufacture of cheese may be rejected by the application of this test.

The constituents of milk useful to cheese-makers are the milk-fat and the casein, as these comprise over 90 per cent. of the solids contained in the cheese. It is obvious, therefore, that the yield of cheese from a given quantity of milk will depend upon the quantity of fat and casein which such milk contains. The purchase of milk according to the butter-fat percentage is the usual practice among cheese-makers, milk which is rich in fat being also rich in casein.

The advantage to be derived from using milk rich in butter-fat is illustrated in the following table compiled by Van Slyke.

TABLE 13

Fat in Milk	Casein in Milk	Amount of Cheese made from 100 lb. of Milk	Amount of Cheese made from each lb. of Fat in Milk
Per cent.	Per cent.	lb.	lb.
3·00	2·10	8·30	2·77
3·25	2·20	8·88	2·73
3·50	2·30	9·45	2·70
3·75	2·40	10·03	2·67
4·00	2·50	10·60	2·65
4·25	2·60	11·17	2·63
4·50	2·70	11·74	2·61
4·75	2·80	12·31	2·59
5·00	2·90	12·90	2·58

The milk when received is usually cooled to 65° to 70° F. Cooling is generally carried out by means of a sterilised surface cooler, but occasionally the milk is cooled in the jacketed cheese vat by passing cold water through the jacket. If the latter process is adopted, the milk should be constantly stirred to ensure even cooling and to aerate the mixture. Stirring is also essential to prevent the cream rising to the surface.

(2) **Ripening the Milk.**—The modern *cheese vat* is usually streamlined and possesses a float bottom. It consists of a wooden or metal outer box which is fitted on inner metal tanks so placed that the base of the inner tank is supported by a wood rack which allows space for steam and water between the two tanks. The inner container is made of tinned copper, nickel, steel or of stainless steel. Wood is generally used for the construction of the outer tank on account of its long life, its insulating properties and freedom from corrosion. Suitable means of drainage for both the inner tank and the intervening space are, of course, essential. Vats, whose outer compartments are constructed of metal, should be painted annually on their external surfaces. The capacities vary from 100 to 1,500 gallons.

The milk is placed in the vat and thoroughly stirred to obtain a uniform composition and acidity. It is then ripened. Ripening is dependent upon bacterial action, the particular flavour developed being, in turn, governed by the organisms present. Each species produces chemical bodies which impart peculiar characteristics to each particular brand of cheese. The ripening process may be carried out in three ways, as follows:

(a) By keeping the milk until sufficient acidity develops by natural means.

(b) By the use of a naturally prepared "starter" made by the souring of clean milk, the clotted milk being tested before addition to the bulk.

(c) By the use of an artificial ripening culture or "starter" composed of *Streptococcus lacticus* propagated in pasteurised milk.

The object of ripening is to increase the acidity of the milk and to assist in the production of a suitable flavour. This is brought about by the multiplication of the lactic-acid bacteria. Artificial "starters" are to be preferred, as these, being grown in purer form, are more vigorous and are more readily able to overcome any injurious organisms which may be present in the milk.

The artificial "starter" is usually prepared daily, the quantity required varying according to the quantity of cheese being manufactured and the milk which is to be used. The proportions vary from 1 quart per 100 gallons of milk for medium-ripening cheese to 2 quarts per 100 gallons for quick-ripening cheese. Clean, fresh, pasteurised milk, cooled to 70° to 75° F., is used and the "starter" is added, the whole being thoroughly mixed. The prepared culture is then stored until the following day at a temperature of 60° to 70° F. Care must be taken to ensure that the culture is not allowed to become too cold, as otherwise the organisms will not develop with sufficient speed. If, on the other hand, the culture is maintained at an excessive temperature, the bacteria will develop with too great rapidity. If the "starter" forms a firm curd, the organisms are not sufficiently active for cheese-making. If the organisms produce too much acidity, they destroy themselves, when it will become necessary to prepare a fresh supply of "starter" daily.

When the "starter" is ready for use, it should be curdled in an even mass and, on stirring, should possess a smooth, creamy appearance. It should possess a clean acid taste and, when tested, should show 0·7 to 0·8 per cent. of lactic acid.

Before the "starter" is added to the milk, a small quantity should be reserved to use for the manufacture of a new supply. This propagation can be carried on until the culture shows signs of weakness. If care and cleanliness are exercised, a culture may last several weeks. The proportion of "starter" added to the milk is increased under the following circumstances:

(a) When very sweet milk is being used.
(b) When the milk is slightly tainted.
(c) If speedy cheese production is essential.
(d) During cold weather.
(e) With small quantities of milk.

The proportion is diminished when—

(a) the milk is acid or ripe.
(b) the weather is warm.
(c) a large quantity of milk is used.

Stilton and Wensleydale cheeses are often manufactured without "starter," although the use of a slight quantity is beneficial.

It is essential that the milk should be properly ripened before the rennet is added, as the action of the latter is aided by the acidity of the milk. It has been found more advisable to add a small quantity of "starter" and leave the milk longer before renneting than to use a large quantity and add the rennet shortly afterwards. If a large quantity of "starter" is added immediately before renneting, a thick granular curd is produced, the resulting cheese being soft and crumbly, besides possessing an inferior flavour. The milk should be retained at a temperature suitable for the growth of the lactic-acid organisms, as it is thus evenly ripened, while the production of acidity is more regular, resulting in a mellow curd. The "starter" should be carefully strained into the milk and thoroughly mixed.

During recent years, difficulties have been experienced on account of *"slow starter"* outbreaks resulting in a sudden failure of the lactic-acid organisms to produce acidity. Slowness is apparent in overripe "starters," due to the organisms being weakened by excess acidity. Other causes are stated to be contaminated milk or milk from diseased udders. The most important cause has been proved to be a bacteriophage infection of the "starter" and the practical remedy for this trouble appears to be the aseptic propagation of the "starter" in a sealed room completely separated from the rooms which house the actual cheese-making and the separation of whey. This difficulty has focussed attention upon artificial methods, carried out by the addition of lactic acid, the necessary ripening enzymes with lactobacilli as a means of providing flavour. No doubt experiments on these lines will result in this practice being widely adopted in creamery manufacture.

Other defects in "starters" are:

(*a*) Overripeness.
(*b*) Gassiness.
(*c*) Yeastiness.
(*d*) Mouldiness.

(*a*) *Overripeness*—This fault is not due to external contamination, but to the ultra-rapid development of acidity before the "starter" is used. It may be due to:

(i) Too heavy inoculation of the mother culture.
(ii) Storage at too high temperatures.
(iii) Stored too long before use.

A normal "starter" has usually an acidity of 0.6 to 0.85 per cent. lactic acid; it should be smooth, firm and velvety and show no separation of whey. An overripe "starter" has an acidity of 1.0 per cent. or more, the whey separates, while it has a strong acid smell and is lumpy. Excessive ripening impairs the growth of the lactic-acid bacteria as beyond one per cent. acidity, the organisms are weakened and tend to die out. If used, acid production in cheese will be slow.

(*b*) *Gassiness*.—This is due to contamination with bacteria which obtain entrance from dirty utensils and the presence of coliform organisms is the chief cause of this trouble. If gassiness develops, the curd will be full of holes and possess an unpleasant aroma. Such "starters" should always be discarded.

(*c*) *Yeastiness*.—"Starter" may develop a yeasty flavour and odour, and large numbers of gas-holes may be present. Yeasts which can resist the acid conditions present are the cause of this defect and these will ferment lactose and produce undesirable by-products. They gain entrance from dust and dirt, and such "starters" should be discarded.

(*d*) *Mouldiness*.—Moulds are sometimes found growing on the surfaces of "starters," which are usually old or overripe. The moulds break down the lactic acid into simpler by-products. The commonest of these is *Oidium lactis*, which appears as a white, velvety growth on the surface of the "starter." Defective "starters" should not be used.

During the ripening operation, colouring matter is added, as desired. Annatto is most often used for this purpose, being thoroughly stirred into the milk to ensure an even tint, shortly before the rennet is added. The

colouring matter should first be diluted with cold water. Half an ounce to 3 ozs. of annatto are used for every 100 lb. of milk, according to the colour desired.

The cheese-maker must be in a position to estimate the actual degree of acidity present in the milk. Experienced workers are said to be capable of performing this test by smell and taste, but if a uniform quality is required, this practice cannot be recommended. Certain tests for the determination of acidity have been standardised, with a view to securing rapidity in practice. The two tests chiefly used are:

(i) The Acidimeter Test.
(ii) The Rennet Test.

(i) *The Acidimeter Test.*—This test estimates the acidity directly. Ten millilitres of milk, to which a few drops of phenolphthalein have been added, are placed in a dish, $N/9$ caustic-soda solution being run into the mixture until a faint pink colour appears. The caustic-soda solution is so standardised that 1 ml. will neutralise exactly 0·01 gram of lactic acid. Thus, if 2 mls. of the caustic-soda solution are required, this corresponds to 0·02 gram of lactic acid, the acidity being therefore 0·2 per cent. This test is not so accurate in the determination of acidity as the rennet test, but may be used for testing the acidity at all stages of the cheese-making process.

(ii) *The Rennet Test.*—This test estimates the acidity in an indirect manner, depending upon the known fact that the greater the acidity of the milk, the quicker is the action of the rennet. Four ounces of milk from the cheese vat are measured into a warm cup, after which 3 to 4 small pieces of straw are placed in the milk; 3·5 mls. of rennet are then added. The test is carried out at a temperature of 84° F., to which level the milk has been raised. The mixture is thoroughly stirred and the time taken for the straws to become stationary noted. This occurs when the milk begins to curdle. The number of seconds which elapse from the time the rennet is added until all movement of the straws ceases measures the ripeness of the milk. Twenty-two to twenty-four seconds is the optimum period in respect of quick-ripening cheeses, nineteen to twenty-one seconds being usual for hard-pressed or slower-ripening varieties.

(3) Renneting.—Renneting or coagulation of the milk is brought about by the addition of rennet, and, without this substance, cheese-making would be impossible. When milk is treated in this way, it is clotted, a curd is formed and whey is liberated, while the protein is broken down during the ripening process. Rennet is usually prepared from the fourth stomach of the calf, although it may also be present in the stomachs of larger animals. It is a combination of several ferments or enzymes, i.e. rennin, which rapidly clots milk and digests the protein; pepsin, which has a similar but weaker action; and rennet peptidases, whose action is not thoroughly understood. Cheese-makers formerly manufactured their own rennet, the result being that no two supplies were identical. This rendered the manufacture of cheese of uniform quality a matter of chance, while the home-made product was also exceptionally crude and liable to give rise to many undesirable taints and flavours.

A completely satisfactory extract of commercial rennet, as we know it to-day, was first produced by Hansen, a Danish chemist. This possessed good keeping qualities and was of uniform strength. Its introduction brought about a very considerable improvement in the manufacture of

cheese. During manufacture, the stomachs are cleaned and inflated, after which they are hung and allowed to dry. When dry, they are cut up into small pieces, macerated and placed in a vessel of water, to which 4 per cent. of boric acid has been added, and are retained at a temperature of 86° F. for approximately five days. The organs are stored for a week in this manner, being stirred frequently during the period. After storage, they are removed and the juice expressed. Rennet may also be synthetically prepared in the laboratory. Such rennet is a pure, clear liquid of uniform strength. One part of rennet is sufficient to clot 5,000,000 parts of milk. Rennet should always be free from organisms capable of producing faults in cheese.

The action of rennet does not cease with the coagulation of the milk and the contraction of the casein. Its action is continued in the cheese, resulting in the formation of soluble proteins. Jensen has reported that rennet exerts a powerful solvent action upon the proteins of milk, this action being assisted by the addition of small quantities of acid. It is also a well-known fact that cheese is more speedily ripened if the quantity of rennet added to the milk is increased, while its bacterial flora and enzymes are important as regards flavour in the final product.

Only good quality rennet should be used in the coagulation process. It is never advisable to keep the material too long before use, but, if it is necessary to resort to storage, this should be carried out in a cool place. It should possess a low pepsin content, and be of uniform strength, while its bacterial and organic matter content should be as low as possible. Following the testing of the acidity of the milk in the manner described on page 189, and providing that such test shows that the milk is sufficiently ripened, the milk is then warmed by the circulation of water round the jacketed vats containing the liquid. The temperature at which the milk is renneted and the quantity of rennet required vary according to the type of cheese being manufactured, which is, in turn, influenced by the acidity, the temperature and composition of the milk, and the strength of the rennet. The rennet is usually tested before being added to the milk.

Renneting is carried out at a temperature of 80° to 91° F. Some 2½ to 4 ozs. are generally required to coagulate 1,000 lb. of milk, but, as previously indicated, this quantity varies according to the variety of cheese. The acidity of the milk, the renneting temperature, and the quantity of rennet added are so regulated that the curd is ready for cutting within a certain specified time. Soft cheeses are set at lower temperatures and coagulated with less rennet. The rennet is usually diluted with cold water to several times its volume before being added to the milk. After the addition takes place, the rennet is thoroughly stirred in order to distribute it evenly throughout the bulk. Care must be taken to ensure that the mixture is not over-stirred, when a broken curd will result. Gentle stirring of the surface to prevent the cream rising must be carried on until coagulation commences. This is determined by flicking the milk with the finger, when, if bubbles remain upon the surface, coagulation has commenced and stirring must cease. The vat is then covered to prevent chilling of the curd. If this is not done, a weak curd will result. The mass is left undisturbed in the vat until the curd is firm.

(4) **Curd Preparation.**—When the curd is compact and firm, it is cut into small cubes by means of a special knife. Curd knives usually go in pairs,

the blades on one being fixed vertically, and on the other horizontally. This enables cubes of uniform size to be cut. The spaces between the blades vary from $\frac{5}{16}$th of an inch to $\frac{1}{2}$ inch. The curd is tested to determine its readiness for cutting, by inserting a finger and lifting upwards through the curd. A clean break, with the liberation of clear whey, denotes that the curd is ready for cutting. The curd is cut in a clean, even fashion, and the whey is allowed to escape. The whey begins to escape immediately, a thin film forming upon the surface of the cubes, which show contraction. Some varieties of cheese are heated to assist in the expulsion of the whey, this process giving the curd an added firmness. The heating is simplified by the use of a jacketed vat, but it must be remembered that the temperature should only be raised very slowly. The curd used in the manufacture of some soft cheeses is not heated, while in other cases it is allowed to soak in the whey before the liquid is drawn off. The heating of the cubes of curd reduces them to approximately one-half their original size.

Before the whey has drained off, its acidity is tested, while the cubes settle to the bottom of the vat. The whey is then drawn off until level with the curd on the bottom of the vat, and is again tested for acidity. When the percentage of acidity is satisfactory, the remainder of the whey is allowed to escape and the curd is gathered in each side of the vat in order to facilitate draining. The draining operations are important. If the whey is run off before the required acidity has developed, the curd will not ripen properly; while, if it is left unduly long in the whey, the curd will become too acid and the cheese will be dry and sour. The curd is considered ripe when it contains the correct percentage of acid and moisture. Most cheese factories pay particular attention to the whey, analysing it for any solids which it may contain. Whey should not contain more than 0·4 per cent. of fat and 0·8 per cent. protein. This limit is never overstepped in a well-managed factory.

When all the whey has been drained off, a solid mass of curd remains, and this, when sufficiently firm, is cut into strips or cubes, which are repeatedly turned to expedite the escape of the whey. With some types of cheese, the curd is tied up in cloths, which are opened at regular intervals to enable the curd to be broken up and thus facilitate drainage. Other manufacturers cut and turn the curd continuously.

Hot-iron tests are made on the curd while it is in the vat, in the following manner. A piece of steel is heated to redness and allowed to cool until black. A small piece of curd is squeezed dry and is then placed on the hot iron and pulled gently away, when strings of curd form between the curd and the iron. The strings should be firm and threadlike. As an example, the case of Cheddar cheese may be cited. If the strings are sufficiently fine and approximately $1\frac{1}{2}$ to 2 inches in length, the curd is considered ready for milling.

When the curd is sufficiently dry and ripe, it is broken up by hand or passed through a curd mill which cuts the material into small pieces of uniform size. If it is found that the curd is draining slowly in proportion to the development of acidity, the curd is lightly pressed to drive out the moisture. The pieces are then spread over the bottom of the vat and kept warm until a satisfactory hot-iron test is obtained. Salt is next added, the usual quantity being $1\frac{1}{2}$ to $2\frac{1}{2}$ lb. for each 1,000 lb. of milk. The salt imparts flavour to the cheese and acts as a preservative, and only the highest-

quality salt should be used. A soft curd is sometimes improved by increasing the quantity of salt added. Approximately one-third of the salt is usually sprinkled on the curd at a temperature of 90° F., the mass being stirred and spread out, and the process repeated until all the material has been added. Coarse-grained salt is preferable for this purpose. After salting, the curd is ready for its final treatment.

(5) **Pressing and Ripening.**—When the salt has been added, the cheese is ready to be prepared for ripening. Some cheeses are not pressed, being moulded and allowed to drain naturally, while others are packed and pressed into moulds. When cheese which requires to be pressed is manufactured, it is usual to heat the curd, which is then placed into cheese hoops lined with prepared cheese cloths. Wooden cheese moulds have been almost entirely superseded by those constructed of tinned steel strengthened with strong wrought iron hoops. Pressure is applied for varying periods, such pressure depending upon the variety of cheese to be manufactured. After it has been pressed, the cheese is bandaged.

The bandaging and dressing process is important. By this means the "finishing touches" are applied, the cheese being given a marketable and attractive appearance. The bandages also prevent any damage to the substance. Different manufacturers use different methods, but in most cases a bandage of tubular form is wrapped round the cheese, an external laced-up bandage being fixed over this. Circular, starched tops are inserted over each end of the cheese. Care must be taken to ensure that the edges of the cheese are not damaged during the dressing operations. Bandages should be made of the highest-quality cloth, while machine-cut circular caps for covering the ends of the cheeses are to be preferred. Such caps give the cheese a more attractive appearance and add considerably to its saleable value.

If cheese requires to be pressed before ripening, it is placed in a cheese hoop after the bandages have been fixed and is then pressed, the pressure applied and the period of time during which it is allowed to operate varying. Several varieties of presses are used, including single and double chamber and side-by-side types, pressure being applied by means of levers and weights or by means of springs. The American gang-press is becoming popular, and both single and double patterns are obtainable When the pressing process has been completed, the cheeses are removed to the ripening room. A certain loss of weight occurs during the pressing and ripening processes. This varies considerably, and, as an instance of such loss, the case of Cheddar cheese may be quoted. Here, the loss per 100 gallons of milk used in manufacturing is approximately as follows:

	Per cent.
Loss in press	9 to 11
Loss in ripening	6 to 8

The *ripening process* requires careful and expert attention. According to Mattick, ripening is controlled by the balance of growth between the different organisms in the original milk, the "starter" and the rennet, by the enzymes in rennet, by the oxygen present, by the physical behaviour of the curd, development of acidity, the presence of moisture, the temperature and humidity of the cheese store, and by several other factors which are at present unknown. The process allows the characteristic flavour of ripened cheeses to develop, and is really a process of decomposition which renders the

cheese liable to attacks by moulds and, in some cases, by animal parasites. The control of temperature and humidity in the ripening room is of vital importance. Low temperatures have been found more advantageous than high. Temperatures between 40° and 65° F. are generally required, the actual temperature being fixed according to the type of cheese to be ripened. Low temperatures prolong the ripening period, but there is less loss of moisture, while a greater yield per gallon of milk will result. The ripening generally takes place in a humid atmosphere, this humidity being maintained by sprinkling the floor of the ripening room with water.

When cheese ripens, physical and chemical alterations occur in the product, the quantity of soluble nitrogen being increased. This renders the product more digestible, while, in addition, the characteristic flavour develops. The chemical changes which occur result from the growth of organisms, together with the action of the enzymes present in the rennet. Cheese-makers were once of the opinion that proteolytic bacteria were vital to the satisfactory ripening of cheese. While in certain soft cheeses these bacteria are plentiful and active, they are unimportant as regards hard-pressed cheeses. Acid-forming bacteria are indispensable in ripening cheese, and it is a well-known fact that cheeses manufactured from fresh milk, which contains few lactic-acid organisms, will not ripen. Acid-forming bacteria grow rapidly during the manufacturing, pressing, and ripening processes.

Hard-pressed cheeses chiefly ripen following the action of ferments, which in turn result from the disintegration of the lactic-acid organisms present in the milk and rennet. The majority of the lactic-acid bacteria are destroyed when the lactose in the cheese is exhausted. When the bacteria disintegrate, they free endo-enzymes, which act upon the protein. The ferments contained in rennet are exceedingly active in bringing about chemical changes in cheese, such changes being evidenced by the increase in the percentage of soluble nitrogen present. Rennet extract contains the ferment pepsin, which finds the acidity furnished by the lactic-acid bacteria ideal for its activities. By its influence, para-casein is partially digested into albumoses and peptones. Rennet also possesses proteolytic properties, but the clotting ferment and the pepsin require the assistance of the lactic-acid organisms, as, in their absence, no acid is formed and no proteolysis takes place. It may therefore be stated that, to ensure satisfactory ripening, the acidity produced by the lactic-acid organisms and the ferments of rennet must both be present.

The *flavours* which develop as the cheese ripens are due to a large number of factors, and differences which arise in the palatability of different varieties of cheese are due to the predominance of one or more of these factors. These factors are the products of the enzymes present in the cheese, and of the lacto-bacilli present, protein degradation and salts in the substance. The flavours are controlled by the manufacturing processes employed, the texture of the cheese, and the conditions under which cheeses are ripened. Other important factors are the use of a virile "starter," the quality of the milk and the absence of contamination in the rennet. It should also be remembered that protein is an additional if subsidiary source of flavours. When cheese is ripening, the fat, sugar, and protein decompose. In hard cheeses, fat hydrolysis takes place slowly, while in soft cheeses it proceeds more rapidly. When cheeses are ripened for lengthy periods, the fat hydro-

lysis induced by bacterial action results in the formation of small quantities of butyric, caproic, and capric acids. As these have characteristic tastes, they add to the aroma and flavour of the finished product.

Cheeses are turned at regular intervals during the ripening process. The period for which they are allowed to ripen is now considerably less than was formerly considered necessary, as milder-flavoured cheeses are most popular.

Types of Cheese

As already indicated, numerous varieties of cheese exist, but in this section only the better-known types will receive mention.

The composition of the various types of cheese differs considerably, the variation being governed largely by the primary ingredient. As regards fat percentage and moisture content, the average composition is as follows:

(1) *Fat Content*   Per cent.
  (a) Cream Cheeses .   .   .   .   . 40 to 80
  (b) Whole-milk Cheese .   .   .   34
  (c) Skimmed-milk Cheese .   . 10 to 22

(2) *Moisture Content*   Per cent.
  (a) Cream Cheeses .   .   .   . 23 to 25
  (b) Whole-milk Cheese .   .   . 30 to 40
  (c) Skimmed-milk Cheese .   . 50 to 60

The conditions prescribed for National Mark cream cheese required a fat content of 55 to 70 per cent. The moisture content of such cheese will therefore be 20 to 60 per cent.

Cream cheeses are usually soft and rich in flavour; whole-milk cheeses possess a good flavour and texture, while skimmed-milk cheeses are usually hard and dry. Some fatty and richly flavoured cheeses, such as Stilton, have cream added to the milk before manufacture.

The principal cheeses to be considered may be classified as follows:

(1) Hard Cheeses.
(2) Blue-veined Cheeses.
(3) Soft Cheeses.
(4) Special Varieties.

A summary of the manufacturing methods used in each case is set out in the following pages.

(1) **Hard Cheeses.**—The principal types of hard cheeses which comprise the main output of our cheese factories are:

(a) Caerphilly.   (g) Gruyère.
(b) Cheddar.   (h) Lancashire.
(c) Cheshire.   (i) Leicester.
(d) Derby.   (j) Swiss.
(e) Gloucester.   (k) Edam.
(f) Gouda.   (l) Butter-milk.

The moisture content of these types of cheeses is relatively low, the curd is heavily compressed to expel the air content and the mass ripens in a uniform manner. The growth and action of extraneous organisms are inhibited to a great extent with the result that such cheeses possess good keeping qualities.

(a) *Caerphilly.*—This white variety of cheese is popular in Wales and South-west England, its original home being the town of Caerphilly. Its manufacture offers the following advantages:

    (i) It is very profitable, owing to its high yield.

    (ii) It can be manufactured throughout the entire year, as very little acidity is required in the process of manufacture.

    (iii) It can be quickly ripened and marketed.

    (iv) It is simple to manufacture.

Because of the quick marketing of the cheese, there is little time for harmful impurities to develop. The product should be consumed not more than fourteen days after manufacture, as it is of a perishable nature, deteriorating in quality one month after production with a rapid loss in weight due to the high percentage of moisture contained in the curd.

This cheese belongs to the whole-milk variety, being manufactured from the evening's and morning's mixed milk. The yield is high, usually 1 lb. 5 ozs. of cheese being obtained from 1 gallon of milk. The evening's milk is strained and cooled to 70° F. in order to aerate it and get rid of any bad flavours, and is allowed to stand until the following morning, being occasionally stirred. In the morning, the cream is skimmed off and mixed with some warm new milk. The mixture is heated to 90° F., the whole being strained back into the vat and thoroughly mixed with the skimmed milk already there. The milk in the vat is then heated to 70° F. and about 2 per cent. "starter" added to develop sufficient acidity (0·19 to 0·20 per cent.) to allow of the rennet being added about half an hour afterwards. The morning's milk is finally added, and the temperature of the whole raised to 86° F.

Rennet, diluted with cold water, is added in the ratio of 4½ ozs. to each 100 gallons of milk, and the whole is stirred until coagulation begins. This is usually ten minutes after the rennet has been added. The vat is covered and left for forty-five minutes, when the curd will be ready to cut.

The curd is cut into small cubes by both horizontal and vertical knives which are gently stirred by hand, while the temperature is raised to 87° F. It is stirred gently by hand for five minutes, steam being admitted to the jacket of the vat until, at the end of approximately fifteen minutes, the temperature reaches 87° F. The curd is stirred gently with a rake until the whey has separated, the curd being allowed to settle to the bottom of the vat. When the whey develops sufficient acidity (0·16 per cent.) it is drawn off and the mass of curd is piled on either side of the vat until 0·22 per cent. of acidity develops. It is then cut into small pieces, cutting and piling being carried on for twenty minutes, care being taken not to break the curd or allow it to become too dry. It is then covered and left for a further fifteen minutes and the acidity will now vary between 2 and 4·5 per cent. according to the nature of the curd. It is now broken into small pieces and salted in the ratio of 2¼ lb. to each 100 lb. of curd. This is well mixed in the curd, which is filled into moulds lined with cheese-cloth. The moulds are next placed in the press under slight pressure for one hour. The cheeses are then turned, the cloths being wrung out in salt water. They are then pressed for some three hours, when they are again turned, rubbed with salt, and re-pressed. Four to six hundredweight pressure is applied until the following day. They are next placed in brine, composed of 1 lb. of salt to each gallon of water, for twenty-four hours, and are drained for a further twenty-four hours, being turned occasionally. They are stored for ripening at a temperature of 60° to 65° F. in a room free from draughts. The ripening period depends upon the atmosphere. If dry and fresh, the process will be completed in ten days, while the period will be prolonged if the weather is close and sultry.

(b) *Cheddar*.—This type of cheese is manufactured in Great Britain in larger quantities than any other variety. It is made from evening's and morning's whole-milk, suitably ripened. The evening's milk is cooled and strained into the vat, where it remains until the following morning. The cream is skimmed and heated to 90° F., and is then strained back into the milk, which has been heated to 70° F. The "starter" is next added in the ratio of 1 to 2 quarts for each 25 gallons of milk, this being sufficient to enable renneting to take place one and a half to two hours after the addition has been made. When the "starter" has been thoroughly mixed in, the morning's milk is added and the mixed milk heated to renneting temperature, i.e. 85° F. An acidity test is then made. This is important, as the acidity of the milk at this stage governs the flavour, texture, and keeping quality of the cheese. If the addition of colouring matter is desired, annatto, diluted to six times its volume with water, is added in the proportion of $\frac{1}{2}$ to 2 ozs. per 1,000 lb. of milk, according to the tint desired. This is thoroughly stirred into the milk.

When the acidity of the milk reaches the required degree (0·19 to 0·23 per cent.), rennet diluted in water is added in the ratio of 1 dram to each 4 gallons of milk, and well mixed in. Coagulation begins in ten minutes, and the milk is gently agitated for a further similar period, to prevent the cream rising to the surface and being lost in the whey when the curd is cut. When the curd breaks clean (usually after forty to forty-five minutes) it is cut into small pieces, being first stirred for ten minutes to facilitate loosening. Care is necessary with this operation, as rough handling will result in serious loss. If the cutting operation has been properly carried out, the whey will have a clear greenish hue.

Ten minutes after cutting, heat is gradually applied, the temperature being raised to 98 to 100° F. at the rate of one degree every three minutes. For milk rich in fat, a slightly higher temperature is required, while for poor-quality milk, a lower temperature will be necessary. The maximum temperature is reached in one hour, and, if the curd is sufficiently firm, stirring should cease and the curd be allowed to settle to the bottom of the vat. When the acidity is 0·16 to 0·17 per cent., the curd is pushed to one end of the vat and the whey drawn off.

The curd is then piled, being cut into 9-inch squares, which are placed on each side of the vat. It is important here that the temperature should not be allowed to fall below 85° F. Cheese-cloths are placed between each layer and the pieces are re-piled after fifteen minutes. The piling process is repeated until the curd is ready for grinding. If gas apertures appear, the piling is continued until these have been eliminated. The curd should eventually become solid and silky in appearance, and, if cut through and pressed, should exhibit no signs of free moisture.

The curd is then ground and spread on the bottom of the vat to cool, being stirred continuously. Stirring reduces the temperature, while the accompanying aeration frees the gases contained in the curd. Salt is then added in the ratio of 2 lb. per 1,000 lb. of milk (a moist, acid curd requires more salt than does a dry curd). The salt preserves the cheese and brings out the desired flavour. When the curd has been salted, it is allowed to stand for fifteen minutes, when it is placed in moulds lined with cheese-cloth. The curd is generally weighed into the moulds to ensure a uniform size of cheese.

The cheeses are placed in the press and light pressure applied. This is increased gradually until a pressure of 1 ton is attained in two hours. This pressure is applied for some four hours, when the cheeses are trimmed, reversed in the moulds, and subjected to 25 cwts. pressure until the following morning. On the second day, the cheeses are bathed in warm water and returned to the press, light pressure being applied. After two hours, the cloths are changed and the cheeses are re-pressed with 25 cwts. pressure. Later in the day, new cloths are inserted, the cheeses are turned and subjected to 30 cwts. pressure overnight. On the third day, the tops and sides of the cheeses are greased with lard to prevent cracking, the bandages and caps fitted, and the cheeses returned to the press and subjected to 30 cwts. pressure.

On the fourth day, the cheeses are removed to the ripening room which is maintained at a temperature of 58° to 65° F. The cheeses are turned daily for the first month, after which they are turned every second day until ripe. The usual ripening period is three to four months.

(c) *Cheshire.*—This cheese is manufactured mainly in Cheshire, although reasonably large quantities are produced in the adjoining county of Shropshire. While its manufacture is practically limited to these counties, it is greatly appreciated throughout the world. Its texture is loose and flaky, while it possesses a mild, mellow flavour which renders it exceedingly palatable. It may be artificially coloured if desired.

Four varieties are usually manufactured, as follows:

(i) Early ripening. (iii) Late ripening.
(ii) Medium ripening. (iv) Stilton Cheshire.

The preliminary operations are similar for all varieties, which are manufactured from whole evening's and morning's milk in every case. The evening's milk is cooled to 70° F. and allowed to stand until the following morning in the vat. The cream is skimmed off next morning and warmed to 70° F. This is added to the morning's milk and the whole is added to the skimmed milk in the vat. "Starter" is added in the ratio of 1 pint to 25 gallons of milk, in order to ensure that renneting may take place within one and a half to two hours. The acidity prior to renneting should be 0·22 per cent.

To colour the cheese, annatto is used in the proportion of 1 dram to each 6 gallons of milk. After the "starter" has been mixed with the milk, the whole is heated to 84° F. The rennet is then added in the ratio of 1 oz. to each 16 to 20 gallons of milk, according to the time of year. The rennet is diluted with five times its own volume of water and is thoroughly stirred into the milk for some five or ten minutes to prevent the cream rising. The curd is usually ready for cutting in approximately fifty to sixty minutes.

The curd is cut with American knives in two directions. The pieces are allowed to settle for five minutes and are then stirred for ten minutes by hand. The curd is stirred with rakes for some thirty minutes, the temperature being gradually raised to 90° F. The curd is allowed to settle and remains at the bottom of the vat for forty minutes. A test is made for acidity and, when this is 0·17 per cent., the whey is drawn off and the curd, after being pushed to one end of the vat, cut into 6-inch cubes. These are placed on cheese-cloths, spread on racks, and turned every fifteen minutes for one and a half hours. When the acidity reaches 0·65 per cent., the curd is milled. When the temperature falls below 80° F., the curd is salted, 1 oz

being added for each 3 lb. of curd.   The salt is thoroughly mixed with the curd, which is then filled into moulds lined with cheese-cloths.   The moulds vary in size from 10 to 15 inches in diameter, being sufficiently large to produce cheeses of 50 to 80 lb. in weight.

The moulds are now placed in a cheese oven and remain at a temperature of 75° F. for twenty-four hours.   No pressure is applied during this period, but clean cloths are placed on the cheeses, which are turned occasionally. The cheeses must not be chilled at this stage or they will not drain properly. After leaving the oven, the cheeses are placed in the press, the pressure being gradually increased until it reaches 25 cwts.   After being pressed for three days, the cheeses are bandaged and removed to the ripening room, the temperature of which is 60° F.   The ripening period varies from four to six weeks.

The medium-ripening type is manufactured in a similar manner to that already described, the main points of difference being:

    (i) Double quantity of "starter" is used.
    (ii) Acidity at renneting is 0·18 per cent.
    (iii) Renneting temperature is 85° F.
    (iv) Acidity at grinding is 0·3 per cent.
    (v) Slightly less salt is used.

This type requires from eight to twelve weeks to ripen.

The late-ripening type is scalded at 90° to 94° F., while excess acidity is prevented by breaking down the curd to a finer degree and by "skewering" the cheese under pressure.   Except for these slight divergences, the process is similar to that used for the medium-ripening variety.

With the Stilton Cheshire variety, the evening's milk is stored at a temperature of 64° F., while the renneting temperature is 86° F.   Sufficient rennet is added to allow of the curd being cut after forty-five minutes.   The curd is finely divided and the whey quickly withdrawn, in order that too much acidity may not develop.   The curd is pressed, but the pressure must never exceed 1 cwt.

(d) *Derby.*—Derbyshire cheeses are 4½ inches deep and 16 inches in diameter, and weigh from 28 to 32 lb., some 30 gallons of milk being required to produce one cheese.   It is only during the present century that a definite method of manufacture has been evolved.   Up to that time, the cheeses possessed little acidity and were sweet to the palate.

This type of cheese is made from mixed evening's and morning's milk but, at the present time, very little is manufactured, as the milk from most of the Derbyshire farms is either disposed of in the adjoining industrial areas or transported to London.   The mixed milk is heated to 84° F., when the "starter" is added in the ratio of 1 pint to every 30 gallons of milk. When the acidity reaches 0·19 per cent., rennet diluted in water is added, 1 oz. to each 30 gallons of milk.   The curd is stirred after cutting until the temperature reaches 94° F.   It is then allowed to settle in the vat and, when the acidity reaches 0·18 per cent., the whey is drawn off.   The curd is cut into large cubes, generally after forty-five minutes, and is piled, the cubes being re-piled every twenty minutes.   When the acidity reaches 0·45 per cent., the curd is milled, salted, and placed in moulds.

The cheese is then pressed, light pressure being applied for the first few hours.   In the evening, the cheeses are placed in clean, damp cloths, and pressed overnight with 10 cwts. pressure.   On the second day, they are

placed in clean cloths and again pressed, 20 cwts. pressure being applied. On the third day, the cheeses are bandaged and removed to the ripening room. Ripening occupies two to three months and takes place at a temperature of 55° F., the cheeses being turned daily. Derby cheeses are often removed to a damp cellar during the last two weeks of the ripening period in order to give the cheeses a good "bloom" and to encourage the growth of mould upon the surface.

(e) *Gloucester.*—Two varieties of this cheese are manufactured, Single and Double Gloucester.

(i) DOUBLE GLOUCESTER.—This cheese is mellow to the palate and possesses a close texture. Mixed milk cooled to 70° F. is used in manufacture, 28 gallons of milk being required for each cheese. The evening's milk is allowed to stand overnight, when the cream is skimmed off and mixed with a portion of the warm morning's milk. This is added to the skimmed milk in the vat, to which the remainder of the morning's milk is afterwards added. One pint of "starter" to each 25 gallons of milk is added, this ensuring that the milk is ready for renneting in one hour. The temperature of the milk is raised to 84° F. Colouring matter may be added in the ratio of 1 dram of annatto to each $2\frac{1}{2}$ gallons of milk. When the acidity reaches 0·19 per cent., 1 dram of rennet is added to each $3\frac{1}{2}$ gallons of milk, the rennet being diluted with 3 to 4 times its volume of water before addition. This is thoroughly stirred into the milk for three minutes, the surface of the milk being slightly agitated until coagulation commences. Three-quarters of an hour after renneting, the curd is cut by means of a curd breaker, this process occupying thirty minutes. The curd is stirred for ten minutes, after which it is scalded at 96° F. During the scalding process, the curd is gently stirred for thirty minutes. It is then allowed to settle, and when the acidity reaches 0·18 per cent., the whey is drawn off. The curd is pressed in the vat with a 10-lb. weight, which is left in position for ten minutes, the curd then being cut into blocks and left to drain. These blocks are turned at intervals in order that acidity may develop. Two hours after cutting, the curd is milled. It is then stirred until the temperature falls below 80° F., when 1 oz. of salt is added for each $3\frac{1}{2}$ lb. of curd. Moulds are filled and subjected to slight pressure. Two hours later, the pressure is increased to 10 cwts. On the second day, the cheeses are placed in clean cloths, turned, and 15 cwts. pressure applied. This operation is repeated on the evening of the second day and on the third day. The cheeses are then removed to the ripening room, where they are allowed to mature for four to six months. They are not bandaged, but are turned daily for the first two months and every second day thereafter. Double Gloucester cheeses are usually 9 inches in height and 14 inches in diameter.

(ii) SINGLE GLOUCESTER.—This is a quick-ripening cheese, 3 inches high and 15 inches in diameter, and possesses a mild flavour and open texture. Each cheese requires 15 gallons of milk, the method of treating the milk being similar to that which applies in the case of the Double Gloucester variety. One and a half pints of "starter" are added to each 100 gallons of milk, the liquid being gently stirred for thirty minutes. The temperature is raised to 84° F. and, when the acidity reaches 0·18 per cent., rennet is added in the ratio of 1 dram to each 4 gallons of milk. The curd is cut forty-five minutes after renneting, the operation occupying approximately thirty minutes. The temperature is then raised to 88° F. This occupies thirty

minutes, the curd being stirred during the entire period.   When the acidity
reaches 0·14 per cent, the curd is piled and the whey decanted.   The curd
is cut into 4-inch blocks, which are turned every fifteen minutes.   The curd
in the vats is then lightly pressed and, when 0·3 per cent. acidity has de-
veloped, is milled, 1 oz. of salt being added to each 4 lb. of curd.   The
wooden moulds are then filled and the cheeses pressed in a similar manner to
that described for Double Gloucester, except that the maximum pressure
is not applied until two days after the cheeses have been placed in the press.
Pressing usually occupies five days, the cheeses being placed in new cloths
daily.   Ripening occupies approximately two months.

(f) *Gouda.*—This is a Dutch cheese made either from whole-milk or a
mixture of skimmed evening's milk and whole morning's milk.   Colouring
matter is thoroughly stirred in before renneting takes place, at 90° F.   The
curd is ready for cutting in fifteen minutes, the operation being performed
by means of a special knife known as a "lyre."   The curd is stirred until
the temperature reaches 104° F., usually some thirty minutes.   The whey
is pressed out in the vat and the curd placed into moulds while warm.   After
remaining thirty minutes in the moulds, the cheeses are pressed for fifteen
hours.   They are then salted, either by immersion in brine or by dry-
salting, after which they are placed in the ripening room, being turned daily
until required for sale or use.

(g) *Gruyère.*—This is a product of Switzerland and is manufactured from
skimmed and whole-milk.   The evening's milk is skimmed, and to this is
added the morning's milk, heated to a temperature of 110° F.   The mixed
milk is allowed to cool to 92° F., after which rennet is added.   The curd which
forms is heated to 140° F., being stirred for one hour.   It is then gathered in
a cloth, lifted out of the vat, and salted in the ratio of 1 lb. of salt to each
25 lb. of curd.   In some cases, salting is carried out by immersing the curd
in brine for four days.   The cheeses usually weigh from 100 to 150 lb., while
9½ lb. of cheese are produced from 10 gallons of milk.   The cheeses are
stored at a temperature of 70° F.   During the ripening process, the apertures
so characteristic of this type of cheese develop, due to the production of
carbon dioxide and nitrogen and to the action of bacteria.

(h) *Lancashire.*—This variety of cheese is not widely known outside the
borders of its native county, although it is exceedingly popular in that area.
It is an excellent toasting cheese, and, when ripened, is soft and mellow and
can be spread like butter.   This is the result of the method of manufacture,
the cheeses being formed from the curds of several different ages.   The
mixing of the curds imparts to the cheese its loose, friable character, while
acidity develops more slowly in this type than in other varieties of hard-
pressed cheese.

Eleven pounds of cheese may be manufactured from 10 gallons of milk
but, during the ripening process, there is a loss of approximately 10 per
cent. due to shrinkage.   The average weight is approximately 40 lb.   Many
cheeses are now made which weigh only 12 lb., owing to the demand for
this size, while prior to the War an extensive trade had developed in extremely
small cheeses weighing 1 lb. each.

The cheeses are manufactured from whole-milk.   The evening's milk is
placed in the vat and, on the following morning, the cream is thoroughly
stirred in and the morning's milk added.   One pint of "starter" to 50 gallons
of milk is added, the milk being allowed to ripen for thirty minutes at 86° F.

One dram of rennet diluted with cold water is added to each 3 gallons and is thoroughly stirred in. Gentle stirring is continued until coagulation begins, the curd being ready for cutting in one hour. This operation is performed with a vertical knife, the curd being cut longitudinally and horizontally. The cheese vat is designed to facilitate the drainage of the curd when the whey has been drawn off. The curd is lifted by a scoop into a drainer, over which a cloth is spread. It is tied into a bundle, slight pressure being applied to force out the whey, after which the bundle is untied and the curd cut into blocks. These are broken at intervals of thirty minutes on four occasions. When the curd is ready for grinding, a portion is stored in a clean vessel at a temperature of 65° F. until the following day. This old curd is finally mixed with the new curd, the proportion of old and new curd being equal.

The mixed curds are ground, 1 oz. of salt being added for each 3½ lb. of curd. The temperature of the mixed curd should be 70° F. when the salt is added. The curd is then filled into moulds, which are inverted until the following day. The cheeses are next turned and placed in the press, 15 cwts. pressure being applied. On the following day, the cheeses are turned and bandaged, pressed again for twelve hours, and afterwards stored in an airy room. When the bandage is dry, a coating of hot whey butter is applied. The cheeses are then ripened, the temperature and time required being as follows:

(i) Quick-ripening cheeses: Four weeks at 65° F.
(ii) Slow-ripening cheeses: Six months at 55° F.

The cheeses are turned daily to ensure even ripening and uniform distribution of moisture. Lancashire cheese possesses very little rind.

(i) *Leicester.*—The manufacture of this variety of cheese is confined to Leicestershire and adjoining counties. It is practically unknown in London, which is rather peculiar, as prime Leicester cheese is considered a delicacy. It possesses a high, bright colour and keeps excellently. The cheeses are some 18 inches in diameter and 4 inches deep, weighing approximately 40 lb. They possess a loose, flaky texture somewhat similar to Cheshire cheese, but are even more "crumbly," while the flavour is exceedingly rich.

This type of cheese can be simply manufactured with a comparatively inexpensive outfit, manufacture taking place largely during the summer months, when there is an abundance of surplus milk for disposal. Mixed whole-milk is used, the evening's milk being stored and cooled overnight. The following morning, it is heated to 86° F., and mixed with the warm morning's milk. One pint of "starter" is thoroughly mixed with each 20 gallons of milk, this being followed by 2 ozs. of annatto to a similar quantity of milk, which gives the characteristic high colour. When the acidity reaches 0·19 per cent., rennet is added in the ratio of 1 oz. to each 20 gallons of milk, the curd being ready to cut in forty-five minutes. The curd is cut in a circular direction with a vertical knife working in a spiral fashion towards the centre, after which it is cut horizontally with the same knife. Two further cuttings are then made with a horizontal knife.

The temperature is raised to 94° F., the whole being stirred continuously. When the hot-iron test shows ¼-inch threads, the whey is run off, the curd being cut into 4-inch blocks, which are piled and turned at intervals. One ounce of salt to each 3 lb. of curd is then added. The cheeses are subject to an initial slight pressure, but the same evening the cheeses are turned and 10 cwts. pressure applied. On the second day, the cheeses are again turned

and 25 cwts. pressure applied until the following morning, when the cheeses are removed to the ripening room. The cheeses ripen for two months, the bandages being removed during the last two weeks in order that the desired blue mould may develop upon the external surface of the cheese.

(*j*) *Swiss.*—This variety is famous for its "eyes," which contain carbon dioxide and are produced by the fermentation of the milk sugar. It is manufactured in steam-jacketed coppers of various sizes, some being capable of dealing with 3,000 lb. of milk. Whole, clean fresh milk is heated to 96° F., sufficient rennet being added to allow the curd to be cut in thirty minutes by means of a special knife known as a "Swiss Harp." The curd is broken into grains and stirred for thirty minutes, the temperature being raised to 130° F. The curd is cooked for one hour, when the pan is inverted, the material falling out into a draining cloth. Pressure is applied by means of a screw fitted to the draining table, the usual pressure being 20 lb. for each pound of cheese. At the end of twenty-four hours, fresh cloths are fitted and the cheeses are either immersed in brine or dry-salted. Care is necessary during ripening, which occupies approximately ten months. The temperature of the ripening room is so regulated that the "eyes" develop at a reasonable speed, but not too rapidly. This variety of cheese is sometimes cut into blocks 20 inches by 6 inches. This method of cutting is said to allow the apertures and ferments to be more easily controlled than is the case with the circular cheeses.

(*k*) *Edam.*—This is the familiar Dutch "cannon-ball" cheese, which has an external colouring of bright yellow or red, the colour depending upon the country to which it is exported. It is made from a mixture of partly skimmed evening's milk and whole morning's milk, which is heated to 93° F. Two ounces of annatto to each 100 gallons of milk are added, followed by 5 ozs. of rennet to a similar quantity of milk. The curd is cut in fifteen minutes, after which it is heated to 94° F., being constantly stirred. The warm curd is filled into special moulds and, after they have been moulded, the cheeses are dipped into hot whey at 126° F. They are bandaged, placed back in the moulds, and subjected to 1 cwt. pressure for twelve hours. They are then salted, either by immersion in brine or by means of special salting moulds, following which they are painted externally with the colours already indicated.

(*l*) *Butter-milk.*—This is chiefly a product of butter factories or of farms which manufacture butter. Difficulty is experienced in using rennet, as the casein in the butter-milk has already been coagulated by acid. This difficulty is generally overcome by neutralising the butter-milk and heating to 140° F. It is then allowed to cool to 90° F., and 1 dram of rennet to every 2½ gallons of milk is added. The whey is drawn off when the coagulation is complete. The curd is then heated to 110° F. by pouring large quantities of whey previously heated to a high temperature into the vat. The curd is allowed to stand in the whey for approximately one hour, when the liquid is drawn off, the curd being cut into cubes and allowed to drain overnight by standing in cloths. Salt is added in the ratio of ½ oz. to each 4 lb. of curd. This is worked into the mass, which is tied into a coarse linen cloth and hung to dry. If large quantities are manufactured, the curd is subjected to 2 cwts. pressure, which is increased to 5 cwts. on the fourth day. Ripening takes place at a temperature of 60° F. and occupies three to four weeks, the cheeses being turned daily.

(2) **Blue-veined Cheeses.**—Several varieties of cheese are brightened by blue-veined moulds, these varieties being highly esteemed in this country. Only three of the following varieties are home-produced:

(*a*) Dorset.
(*b*) Gorgonzola.
(*c*) Roquefort.
(*d*) Stilton.
(*e*) Wensleydale.

Blue-veined cheeses possess a high moisture content and have a soft curd. They are not only ripened by the normal organisms, but also by the growth of moulds throughout their substance.

(*a*) *Dorset.*—This type is chiefly produced in the counties of Dorset, Devon, and Somerset, where it is named "Blue Vinney" (or Vinny). Its production has declined during the last few years owing to the attractions of the liquid-milk market. When ripe, the cheeses average 16 lb. in weight, and are 12 inches in diameter by 5 inches deep. The coat is rough and brown in colour, the cheese being loose and crumbly in texture, while the blue mould should be evenly distributed throughout the texture.

This cheese is manufactured from skimmed milk. Hand-skimmed milk is preferred, as a small percentage of fat remains in the milk and acidity develops slowly and naturally. If all the fat is removed from the milk, the resulting cheese will be hard and dry. The morning milk is placed in shallow pans, the cream being skimmed twice, at two twelve-hourly intervals. The evening's milk is allowed to stand overnight, being skimmed the following morning, and is then mixed with the previous morning's milk in the vat. It is then heated to 74° F. and, when the acidity reaches 0·35 per cent., rennet diluted with water is added in the proportion of 1 dram to each 6 gallons of milk, and thoroughly stirred in. The milk is gently agitated on the surface until coagulation begins. The curd is cut with American knives after eighty minutes and is allowed to stand for ten minutes, after which it is stirred by hand for five minutes. It is then allowed to settle and stand for one and a half hours, when the whey is drawn off. After the curd has drained, it is cut into 6-inch blocks which are turned every twenty minutes until the acidity reaches 0·9 per cent. The curd is hand- or machine-milled and salt is added in the ratio of 1 oz. to each 2½ gallons of milk.

The curd is placed in wooden moulds, which are pressed for four hours with light pressure. The cheeses are rubbed with salt, placed into clean cloths, and 10 cwts. pressure applied. Next morning, the same procedure is carried out, but in this case pressing ceases at the end of two hours. The cheeses are wiped with cloths wrung in warm water and removed to the ripening room. This should be slightly damp, fairly dark, and should be maintained at a temperature of 50° to 60° F. The ripening period varies, soft moist curds maturing in some eight weeks, while hard curds require six months or even longer. The cheeses are turned daily, the external coat which develops being scraped off at weekly intervals.

(*b*) *Gorgonzola.*—This Italian cheese enjoys considerable popularity in Great Britain. It is manufactured in many countries, whole-milk being required for its production.

"Starter" is required to ripen the milk, and, when the acidity reaches 0·27 per cent. and the temperature of the milk following heating reaches 80° F., the rennet is added. When the curd is firm, it is cut into small

cubes, which are placed in special moulds with perforated sides and bases. Alternate layers of curd and powdered bread-crusts carrying the ripening moulds are inserted until the moulds are full. They are then set to drain, being turned several times daily. A slimy mould develops upon the surfaces while the cheeses ripen. This is scraped off and, to allow air to obtain entrance and so assist the blue mould to develop, apertures are bored through the cheeses. This variety ripens best in a cool atmosphere.

Gorgonzola cheese is irregular in quality and the blue mould or veins are never evenly distributed. To prevent shrinkage, an artificial rind is often provided. This is composed of barium sulphate, coloured pink with iron oxide, the whole being coated with tallow or lard. Annatto is occasionally used for colouring purposes. The rind may attain $\frac{1}{2}$ inch in thickness, in some cases being as much as 25 per cent. of the entire cheese.

(c) *Roquefort.*—This cheese was originally a product of Southern France, and it is stated that it has been noted for over one thousand years. It has always been considered a great delicacy by epicures. Large quantities are now manufactured in other countries, but even when produced from goat's milk in the traditional manner, such cheeses are not recognised by the French Government as Roquefort cheese. The genuine Roquefort is made from goat's milk, but a similar type is made from sheep's milk, which averages 8 per cent. of butter-fat, or from a mixture of cow's and goat's milk. Cheese-making premises in the Roquefort district are forbidden to have any milk other than goat's milk upon the premises.

The milk, which is ripened at 80° F., is renneted by the addition of 4 ozs. of rennet to each 100 gallons of milk. The curd is ready to cut in one and a half to two hours and, after cutting, is stirred gently for a short period. The whey is withdrawn and the curd placed in a cloth to drain. It is then filled into moulds, the ripening moulds being added in the proportion of 1 part to each 10,000 parts of curd. The ripening mould is prepared in the following manner. A hot loaf of bread is dipped into paraffin and is inoculated with the Roquefort organisms, by means of a pipette. The loaf is then placed in a dark moist cellar to incubate for a month, after which it is ground and is ready for mixing with the curd.

In the Roquefort district, the milk is turned into curd and to this is added the culture *Penicillium glaucum* which provides the distinguishing flavour. The cheese is sent to the curing caves where it is rubbed with salt and is then passed on to the "brusher" who cleans the cheese, and the "pricker" who punctures it to allow the moist air to enter which ensures the development of the characteristic coloured veins. The cheeses are ripened for four to six months in the famous caves, around which the industry centres. These are no longer caves, in the accepted sense of the word, but great curing rooms with vaulted ceilings and massive supporting pillars of natural rock. Large insulated store rooms have been provided in which a temperature of 32° F. is maintained and the cheese is stored at this temperature until it is thoroughly ripened. The air is exceptionally moist and the temperature never exceeds 46° F. In other countries where cheeses of this type are produced, they are ripened in cold rooms. During the ripening process, the cheeses are sprinkled with salt, being piled three days in succession.

Outside France, this type of cheese has been manufactured from homogenised milk which ripens in a comparatively short time and possesses the regular white colour comparable with the French cheese produced from

sheep's milk; in addition, the body of the cheese is unusually soft so that it may be readily spread with a knife. As no cheese produced in this manner has been kept for any extended period, information as to its keeping qualities is not available.

(d) *Stilton.*—Stilton cheeses were first manufactured in the village of that name, and, from possessing solely a local reputation, the fame of this variety has spread until it is now world-wide. This cheese is usually manufactured from whole-milk, although cream is sometimes added in order to increase the mellowness and richness of the finished product. The usual size is approximately 7 inches in diameter by 15 inches deep, the cheeses possessing a wrinkled coat. The texture is mellow and is accompanied by an attractive flavour.

The cleanliness and freshness of the milk used in the manufacture of this. cheese are of vital importance. The evening's milk is strained and cooled and allowed to stand overnight, when it is heated to 85° F. It is then renneted by the addition of 3 ozs. of rennet for each 100 gallons of milk, the mixture being thoroughly stirred. The surface is gently agitated to prevent the cream rising. After seventy-five minutes, the curd should have formed, and when it is set firm, it is ladled into straining cloths, 1 yard square. The scoop used for ladling cuts the curd into slices, and this assists the drainage of the whey. Three to four gallons of curd are placed into each cloth, these being allowed to stand in the whey for one hour. The whey is then drawn off and the bags of curd are lifted out of the vat and allowed to drain for thirty minutes. The cloths are tightened and turned every thirty minutes, until 0·2 per cent. of acidity develops, when the curd is emptied out of the cloths on to a drainer, where it is allowed to remain until the acidity reaches 0·25 per cent. It is then cut into 4-inch cubes and piled on the drainer, being turned occasionally. When the drainings from the curd show 0·5 per cent. of acidity, the curd is broken by hand, 1 oz. of salt being added for each 4 lb. of curd. The curd is next packed into perforated moulds, which are placed on calico-covered boards. The moulds are placed in a room at a temperature of 70° F., where they remain for approximately one week, being turned every day on to clean boards and clean cloths. Steel skewers are driven through the perforations into the cheeses during the first three or four days. When the cheeses are sufficiently firm to stand, they are scraped until smooth and any crevices filled in.

The cheeses are then bandaged and replaced in the moulds, the process of scraping and bandaging being carried out daily until the peculiar wrinkled coat appears. Scraping then ceases. The cheeses are next removed to the ripening room, where they are stored at a temperature of approximately 60° F. The average ripening period is four months. A humid atmosphere is desirable for this process as, if the air is too dry, the cheeses will crack. During ripening, the cheeses are thoroughly brushed each day in order to disperse the cheese mites, which are exceedingly active. The blueing process is often accelerated by piercing the cheeses with a sharp knitting needle. This allows air to enter the interior of the cheese and assists the growth of the desired blue mould.

(e) *Wensleydale.*—This is a Yorkshire cheese produced from clean whole-milk, which has only become widely known during recent years. The size is similar to that of Stilton, the cheeses weighing some 12 lb., although a flat type of cheese weighing 8 lb. is also manufactured. The cheeses possess

a greyish-white skin, the bandage marks showing clearly upon their outer surfaces. If of good quality, the cheese is soft and flaky and will spread like butter, while the blue veins are well distributed throughout the substance. The flat type is white, soft, and crumbly, being sold in the early stages of ripening, when the blue mould is not properly developed. Cream is sometimes added to the milk in order to impart an added mellowness and smoothness of texture.

During manufacture, the evening's milk is cooled to 70° F. and allowed to stand overnight to allow the cream to rise. The following morning, the cream is skimmed off and the morning's milk is added and thoroughly stirred in, while the temperature of the mixed milk is raised to 84° F. The cream removed from the evening's milk is then heated to 90° F. and is thoroughly stirred into the milk. "Starter" is added in the proportion of 1 to 2 ozs. for each 12 gallons of milk. When the acidity reaches 0·19 per cent., rennet is added in the ratio of 3 drams to each 12 gallons of milk, the rennet being diluted with cold water to five times its bulk. The milk is thoroughly stirred for five minutes, while the surface is agitated for a further period to prevent the cream rising.

The curd is ready to cut in sixty minutes. It is cut in two directions with a vertical knife, and after five minutes is again cut. After a further five minutes the curd is stirred gently for twenty minutes, when it is scalded, the temperature being raised to 88° F., stirring being continued until the curd is firm. It is then allowed to settle until the acidity reaches 0·14 per cent. It is next placed on racks covered with straining cloths and is left, partly immersed in the whey, until the acidity reaches 0·2 per cent. The remainder of the whey is drawn off and the curd is cut into large cubes, which are turned every fifteen minutes until the acidity reaches 0·4 per cent. The curd is then milled or broken by hand and salted, 8 ozs. of salt to 30 lb. of curd being thoroughly mixed in. The curd should not be roughly handled, as a certain looseness is essential in order that this blue mould may develop.

The curd is filled into moulds lined with coarse cloths. These are allowed to stand until the following morning, when the cheeses are turned into fresh cloths and placed into the presses, the pressure being gradually increased to 3 cwts. In the evening, the cheeses are removed to the ripening room, where they are stored for six months. A moderate temperature and a moist atmosphere are essential for satisfactory ripening. The cheeses are turned daily for the first six weeks, and then every second day until ripe.

(3) **Soft Cheeses.**—The production of soft cheeses was the prerogative of Continental countries for many years, but their increased popularity in this country has encouraged manufacturers in districts possessing an equable climate to produce these varieties. These cheeses are extremely palatable and if a sufficiently good market exists, they will be found to be very profitable. Little equipment is required for manufacture and, owing to their high moisture content, the yield of curd per gallon of milk is high.

This type of cheese is usually small in size, is not pressed, and is quickly ripened. The whey is never fully drained from the substance, the curd being allowed to drain naturally. It is usually manufactured from fresh, sweet milk, the acidity developing *after* the rennet has been added. The cheeses are not subjected to heat or pressure, and, as the whey is allowed to drain naturally from them, they contain a considerable quantity of

moisture. The temperature of manufacturing and ripening rooms must be warm and steady or the curd may become chilled and the drainage checked. Owing to their soft, moist condition, they afford a favourable ground for the growth of various organisms and ferments, which ripen the cheeses rapidly and develop "high" flavours. The ripening process proceeds from the surface towards the centre, the bacteria and moulds responsible for the process being aerobic. Their poor keeping quality has tended to restrict distribution to the immediate area of manufacture. Keeping quality is a bacteriological problem involving the prevention of yeast and mould contamination, while suitable packing methods are also necessary.

It is essential that the cleanest possible milk should be used for soft-cheese manufacture, and for this reason, the milk is often pasteurised to ensure its cleanliness, and quickly cooled to the renneting temperature. Milk which has a high fat content will produce a curd which retains more moisture than curd obtained from a milk low in fat; therefore, if possible, a rich milk should be used. Acid milk is undesirable as this yields a firm curd which is not required for soft cheeses, and the highest quality cheese is produced from sweet, fresh milk. If the milk is pasteurised, one drop of "starter" must be added for each gallon of milk immediately before the addition of the rennet, while rather more rennet is required than is normally the case. The principal varieties of soft cheeses are:

(a) Bondon.	(g) Gervais.
(b) Brie.	(h) Limburger.
(c) Cambridge.	(i) Neufchatel.
(d) Camembert.	(j) Parmesan.
(e) Colwick.	(k) Pont L'Eveque.
(f) Coulommier.	

(a) *Bondon.*—In the manufacture of this cheese, sour milk or butter-milk is required in addition to fresh milk. One half-pint of sour milk or butter-milk is added to the fresh milk and the whole is heated to 65° F. One cubic centimetre of rennet is added for each 2 gallons of milk. The milk is set in the evening, the curd being ladled into cloths the following morning, to drain. When drainage is complete, the curd is placed into a fresh cloth, to which a pressure of several pounds is applied. A small quantity of salt is mixed with the curd, which is then placed in moulds which, in turn, are placed on straw mats until properly drained.

(b) *Brie.*—This is a French cheese manufactured from whole or partly skimmed milk. The milk is renneted as it comes warm from the cow, the temperature being approximately 84° F. Two hours after the rennet has been added, the curd is cut, ladled into moulds, and allowed to drain for twenty-four hours. The cheeses are then removed and a small quantity of salt spread upon the surface.

(c) *Cambridge.*—This cheese quickly deteriorates, and is therefore not manufactured in large quantities unless a ready sale is obtainable. The milk is heated to 92° F. Rennet diluted with six times its volume of water is added in the proportion of ½ dram to each 1½ gallons of milk. The rennet is thoroughly stirred in and the milk allowed to stand to allow the cream to rise. The curd when firm is placed in perforated wooden moulds, laid on straw mats. The curd adheres to the sides of the moulds, while the cheese settles first in the middle. The cheeses are not turned, and

when they are sufficiently firm to stand without losing shape, the moulds
are removed. The ripening period is usually two days. Each cheese
weighs just over 1 lb.

(d) *Camembert.*—This is one of the most popular varieties of soft cheese,
being originally a product of France. Whole-milk is generally used in its
manufacture, although sweet skimmed milk may be mixed with new milk
in the proportion of 1 to 5. The cheeses are small, weighing some $\frac{3}{4}$ lb.,
twelve cheeses being obtained from $5\frac{1}{2}$ gallons of mixed milk. This type
of cheese is generally manufactured during the winter months, as great
difficulty attends its production during warm weather.

Evening's milk, fresh and warm from the cow, is strained into wooden
tubs, each containing approximately 6 gallons. The milk is renneted at
a temperature of 82° F., $\frac{1}{2}$ ml. of rennet diluted with six times its own
volume of water being added for each gallon of milk. Coagulation takes
place in two hours.

The Camembert mould is not present in English dairies and, when this
type of cheese is manufactured in this country, artificial inoculation is
essential. In such cases, $\frac{1}{2}$ oz. of ripe cheese, obtained from just below the
rind, is dissolved into a $\frac{1}{2}$ pint of water heated to 75° F. The mixture is
strained into the milk before renneting, and thoroughly stirred in.

When the curd is ready, it is ladled into perforated moulds, which
stand on straw mats upon a perforated draining table. These moulds are
allowed to stand overnight and, during this period, lose half their original
bulk. When the curd from the morning's milk is coagulated, it is filled
into the moulds in order to restore them to their original level. The two
curds are allowed to drain at a temperature of 65° F. When they are
thirty-six and twenty-four hours old respectively, they are carefully turned.
This process requires considerable skill. After standing some hours, the
cheeses are salted, fine salt being rubbed into the upper surface and sides.
The remaining surfaces are salted when the cheeses are turned, several
hours later.

The cheeses are turned several times daily for the first few days, salt
being added on each occasion. They are removed to the ripening room
when firm and held at a temperature of 60° F. When the moulds grow,
the temperature is reduced to 55° F., storage being carried out at this tem-
perature until the external surfaces become sticky, or until the cheeses
are ripe. During the ripening process, the cheeses are turned daily. The
exterior becomes covered with a white mould, which, at the end of three
weeks, becomes grey and later turns brown. The cheeses become liquefied
during the process. This change commences externally and penetrates to the
centre, leaving the final consistency of the cheeses similar to that of butter.

(e) *Colwick.*—This variety is named after the village of Colwick, near
Nottingham. Stale milk mixed with separated milk is sometimes used in
its manufacture, although fresh, warm milk is preferable. The temperature
of the milk is raised to 84° F. and 1 dram of rennet to each 4 gallons of milk
is added. This is thoroughly stirred into the milk for five minutes. At
the expiration of one hour, the curd is firm and is ladled in slices into
the characteristic tubular moulds. The moulds are left for twelve hours
to drain, the cloths removed, and the cheeses ripened for several days,
after which they are usually sold. Sometimes, however, the cheeses are
ripened for longer periods.

(*f*) *Coulommier*.—This cheese, which is white in colour, is usually sold when three or four days old, although on occasion it may be ripened for two to three weeks. If ripened, it loses some 25 per cent. of its weight. The cheeses are small, flat, and circular in shape, and 1 gallon of milk will produce two cheeses weighing approximately 1 lb. each. Whole-milk is heated to between 82° and 86° F., and 1 ml. of rennet is added for each 2 gallons of milk. The milk is stirred for a few minutes at ten-minute intervals and then the upper surface of the milk is kept stirred to prevent the cream rising until coagulation occurs. When the curd is firm (usually after two to three hours), the two-piece moulds, which are shaped like hoops and when fitted together measure 5 inches in height and have a diameter of $5\frac{3}{4}$ inches, stand upon straw mats and are carefully filled and left to drain overnight. When the curd has sunk sufficiently, usually after eight to ten hours, the upper portion of the mould is removed and a straw mat and board placed over the cheese. The cheeses are then turned. This process is repeated twice daily and, when the cheeses are firm, salt is well rubbed in, the cheeses being quickly ready for use. If consumed fresh, they are ready in three days. When ripened for three to four weeks, the cheeses are turned daily.

(*g*) *Gervais*.—Gervais or Petit Suisse cheeses are manufactured from a mixture of 1 part of cream to 2 parts of milk. The mixture is heated to 63° F., 1 ml. of rennet diluted with ten times its own volume of water being added for each $1\frac{1}{2}$ gallons. The mixture is then covered and allowed to stand until the following morning, when the curd is cut and hung in cloths to drain. Salt is added to the curd when firm and moulds, $2\frac{1}{4}$ inches by $1\frac{3}{4}$ inches, are filled. These moulds are lined with blotting-paper. When the cheeses are firm, they are turned out of the moulds on to straw mats. The cheeses are generally consumed when fresh, but, on occasion, are left for two or three days. This type is more gritty in texture and crumbly than cream cheese and may be kept for a longer time before consumption.

(*h*) *Limburger*.—This cheese is a Belgian product and possesses a very strong odour. It is manufactured from fresh milk, which is heated to 90° F. Rennet mixed with forty times its bulk of water is added, in the ratio of 3 oz. to each 100 gallons of milk. The temperature is raised to 96° F., the curd being thoroughly stirred in order to expel the whey. One hour after renneting, the curd is ladled into special open moulds. These are placed upon a draining table and are turned frequently. After twenty-four hours, salt is applied to all external surfaces. The salting and piling of the cheeses is carried on for four days, after which they are ripened.

(*i*) *Neufchatel*.—Very little rennet is used in the manufacture of this type of cheese, and the milk is usually set at a low temperature. Separated milk or mixed skimmed and whole-milk are used in manufacture, but, for a high-quality cheese, whole-milk to which cream has been added is required. This mixture is heated to 72° F., and a "starter" is often added. One ounce of rennet is added to each 100 gallons of the mixture, the curd being ready for cutting in approximately twelve hours. Light pressure is applied to the curd to ensure proper drainage, while $2\frac{1}{2}$ ozs. of salt are added for each 10 lb. of curd.

The curd is passed through a machine similar to a butter blender, which kneads it thoroughly. It is then transferred to a moulding machine,

which divides the mass into blocks. These are wrapped in greaseproof paper or tinfoil.

(*j*) *Parmesan.*—This cheese is of Italian origin and is usually manufactured from half-skimmed goat's or cow's milk. The milk is placed in large, steam-jacketed copper kettles and is allowed to stand overnight. On the following morning, it is skimmed and heated to 75° F. Sufficient rennet is added to cause the milk to curdle in one hour. A few grains of sulphur are added and the whole is stirred and heated until the temperature reaches 130° F., following which it is allowed to stand for fifteen minutes. The greater part of the whey is run off, and curd being collected in cloths and allowed to drain. It is then filled into large moulds, salt being applied to the external surfaces after three or four days. The cheeses are ripened in approximately twelve months, although the process may require any period up to three years.

(*k*) *Pont L'Eveque.*—This type of cheese was first manufactured in the French town from which it takes its name, and although it is said to keep well, having a firm texture, it is usually sold within three weeks of production. The cheeses weigh approximately 1 lb. each and possess a brownish-red exterior. Whole, fresh milk, to which is added a few drops of "starter," is heated to a temperature of 94° F., rennet being added in the ratio of 1 dram to each 2 gallons of milk. The milk is allowed to stand for approximately one hour, when the curd is cut into 2-inch cubes with an ordinary knife, being again cut diagonally after a further five minutes. The curd is ladled into coarse cloths, which are tightened every fifteen minutes until it is usually firm enough to mould. This generally takes two to three hours. After draining, the curd is filled into small rectangular moulds, using $\frac{1}{4}$ oz. of salt to each layer of curd, and these are placed on straw mats to drain, being turned on to fresh mats at half-hourly intervals. On the following day, $\frac{1}{2}$ oz. of salt is rubbed in and the moulds are turned twice daily. When the cheeses are sufficiently firm, they are scraped to fill any crevices which might harbour cheese flies or mites. The cheeses are stored at a temperature of 64° F. and turned daily until a white mould appears upon their surfaces, usually from three to four weeks, when they are removed to a cooler room. They are stored in a tightly packed condition to prevent any evaporation losses during ripening.

(4) Special Varieties.—Two types of cheese exist which cannot be classified under the three previous headings. These are:

(*a*) Cream Cheese.

(*b*) Crustless Cheese.

A brief description of the methods employed in their manufacture is as follows:

(*a*) *Cream Cheese.*—This type is extensively manufactured in this country, particularly during the summer months and, strictly speaking, should be produced from cream. Many varieties exist, although some of the so-called cream cheeses contain very little cream, falling more correctly into the category of soft cheeses. The two varieties of what may be really termed cream cheese are defined in the Agricultural Produce (Grading and Marking Cheese) Regulations, 1935. These are:

1. Selected, 55 per cent. of butter-fat.
2. Extra Selected (double cream), 70 per cent. of butter-fat.

Cream intended for cheese-making should be fresh and sweet. The methods of manufacture for both varieties are similar, except that while the double-cream variety sours naturally, rennet is used to coagulate the single-cream variety.

(i) SELECTED CREAM CHEESE.—Thin cream containing between 12 and 20 per cent. butter-fat is mixed with an equal quantity of milk and the
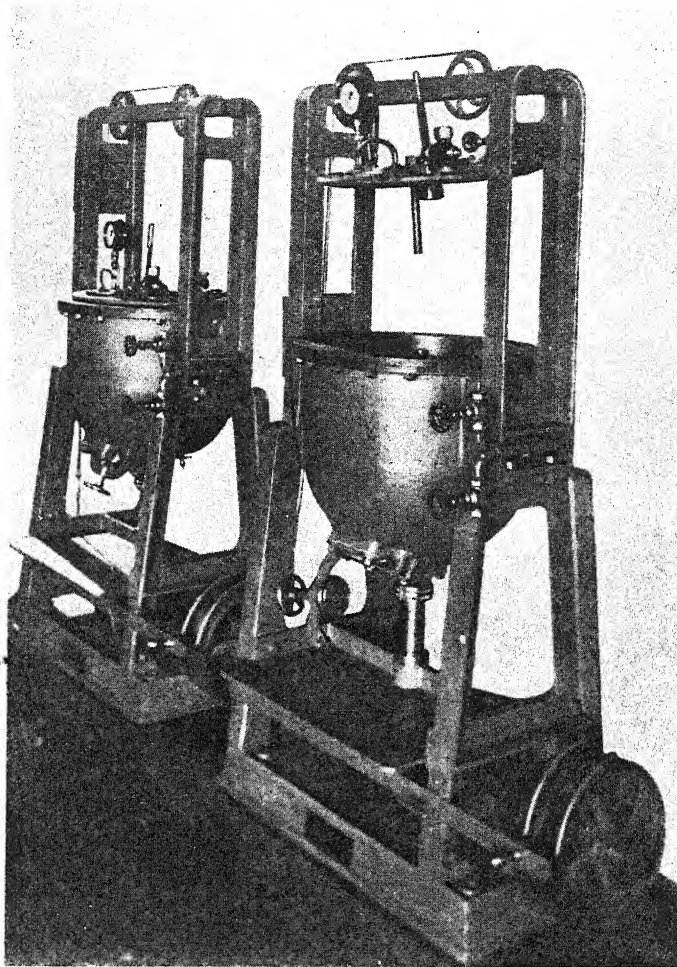
By courtesy of G. J. Worssam & Son, Ltd.

FIG. 52—Cooking Pans for Pasteurised Cheese

mixture is heated between 60° and 65° F. Rennet is added in the ratio of 1 ml. to each quart of cream, together with a small quantity of "starter." The rennet, which is diluted with five times its own bulk of water, is thoroughly stirred in, the mixture being allowed to stand for three hours. When coagulation is complete, the curd is ladled into cloths, which are tied and hung in a dry, airy place. The cloths are untied several times daily, scraped, and the curd thoroughly mixed. The cloths should be changed daily. The curd will drain in approximately forty-eight hours,

but, to accelerate drainage, it should be placed between two boards and a weight of 5 lb. laid over it.   If this procedure is followed, the curd can be moulded in twenty-four hours.   Moulds of various shapes are used. When ready for moulding, the cream should have a thick, pasty consistency. When the cream is emptied from the cloths, it is thoroughly mixed, a small amount of salt being added.   It is then filled into moulds, and is ready for use in three to four days.   This class of cheese should be stored in a cool place and consumed quickly, as, after some ten days have elapsed, it begins to lose both flavour and appearance.
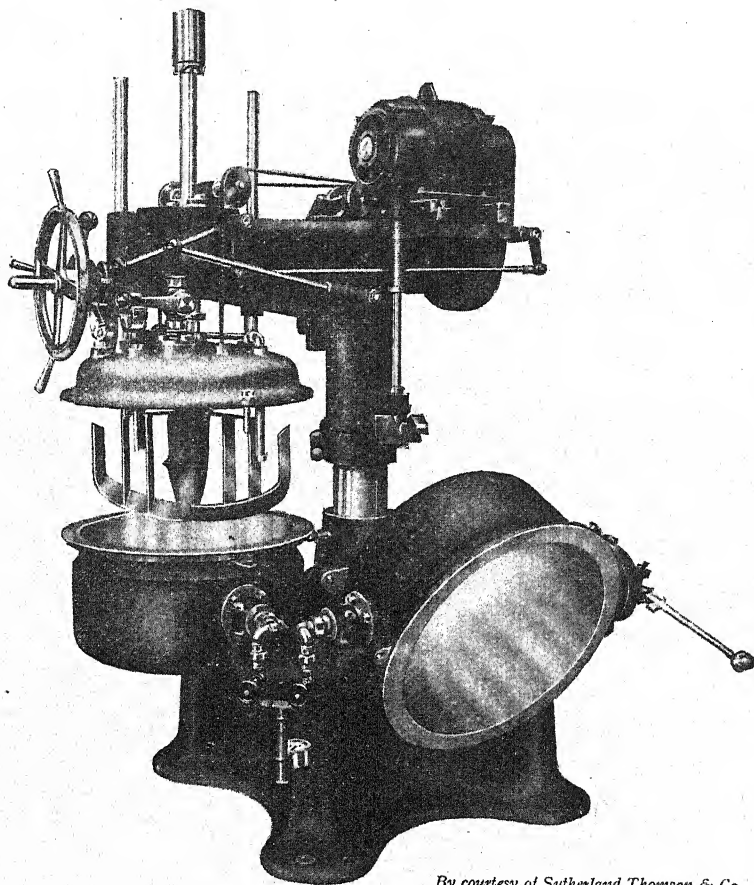
By courtesy of Sutherland Thomson & Co.

FIG. 53—"Kustner" Vertical Cheese Mixing and Melting Machine

(ii) EXTRA SELECTED CREAM CHEESE.—Thick cream containing from 40 to 50 per cent. butter-fat is required for the manufacture of this variety of cheese, and such cream should be efficiently pasteurised and cooled by cold, running water until the temperature falls below 65° F.   The cream is allowed to stand at this temperature for twelve hours, and, at the end of this period, is placed in cloths and hung to drain in a cool, airy place. The cloths are opened every four hours and the cream scraped down.   This permits the hardened cream to make way for the liquid cream from the interior.   When firm, salt is added and the cream is packed into various-

shaped moulds. The cream is sometimes lightly pressed by means of a 5-lb. weight. If the cheeses are to be kept for any length of time, the cream should be soured. This variety of cheese is usually sold fresh, in which state the cheese is extremely perishable.

The essentials of a satisfactory cream cheese may be stated to be:

(i) Sweet to the palate.
(ii) Carefully cooled and prepared.
(iii) Ripened at a low temperature.

Such cheeses taint readily, and all cloths and utensils used during the process should therefore be kept in a thoroughly clean condition. Cream cheese which is to be ripened should never be allowed to ripen naturally. If this is done, unwanted taints may develop and result in a greasy cheese which rapidly becomes rancid.

Glascine - lined aluminium foil and tinfoil are the best wrapping materials. Muslin wrappers reduce the keeping qualities of this type of cheese.
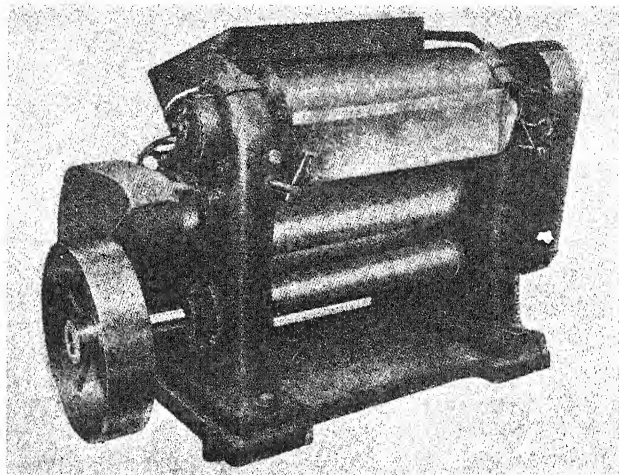
By courtesy of Sutherland Thomson & Co.

FIG. 54—"Kustner" Roller Refiner for Cheese

(b) *Crustless Cheese.*—The manufacture of this type of cheese is practically a new industry, but is one which has been continually expanding, with great profit to the manufacturers and with benefit to the consumers. The two principal types of crustless cheese are the Gruyère variety, manufactured in Switzerland, and a melted Cheddar, manufactured in this country and in America, although Gorgonzola, Roquefort, and Camembert are also available. Forty per cent. of the cheese marketed in the United States of America is the processed variety, while such cheese has proved invaluable for use in tropical climates. This type is usually packed in small portions, wrapped in tinfoil. Crustless cheese possesses many advantages. Manufacturers may make use of cheese of varying textures and ages which, by judicious blending, may be manufactured into a final product. This, if suitably packed, will keep indefinitely and retain the qualities of the original product. Furthermore, while complicated machinery is employed in its production for reasons of economy, a really good crustless cheese may be economically manufactured with simple apparatus, provided care is exercised in the selection of the raw cheese and in the choice of emulsifying agents. The advantages of this type of cheese are:

(i) The packages are attractive, a psychological factor which increases consumption to no small degree.

(ii) The cheese is soft and packed in portions of a reasonable size.

(iii) The keeping quality is satisfactory and the cheese does not become dry, thus eliminating waste.

A process of pasteurisation is used in the manufacture of the Cheddar type of crustless cheese. It is usual to select a number of cheeses of varying ages and flavours, since, by this method, a distinct flavour and uniform quality can be more readily obtained. The crusts are carefully removed, and the cheeses are cut into slices by means of a shredding machine. The slices from various kinds of cheeses are now blended together and are fed into a special grinding machine, which cuts the slices into small pieces. This material is conveyed to a steam-jacketed vat provided with a lid to which balance weights are attached. A charge of grated cheese is inserted, together with a certain amount of lactic-acid solution, the steam is turned on gradually and an agitator set in motion. If a uniform colour is desired, annatto is added, together with sufficient water to make good any losses which occur through evaporation. The agitator is operated at a steady rate and a temperature of 140° F. is reached in twenty minutes. The steam is turned off at this point. The temperature continues to rise, but is not allowed to exceed 150° F. The continued agitation and the application of heat reduce the mixture to the consistency of a thick cream. When the cheese is cooling, a tendency occurs for the fat to separate and to float upon the surface. This is prevented by the addition of sodium phosphate in the proportion of 5 lb. per 100 lb. of cheese, together with 5 to 10 lb. of water, or by the addition of 2 per cent. sodium citrate. Some cheese pasteurisers work under a vacuum.

By courtesy of Sutherland Thomson & Co.

FIG. 55—"Kustner" Crustless Cheese Filling Machine

When the cheese is smooth, with a toffee-like consistency, it is passed to a filling machine which fills boxes or moulds; or it is fed to an automatic packing machine which packs the cheese into portions of various shapes. This plant is entirely automatic in action, the cheese being moulded, cut, wrapped, and labelled by the machine. The operator removes the packages and fills them into boxes. All parts of the filling and packing machines which come into contact with the cheese are constructed of stainless metal. These machines are constantly being improved. The cheese, after packing, is ready for distribution when cool, and will keep in good condition for three months. If the cheese is intended for export to tropical climates, it is heated to 170° F. and held at this temperature for thirty minutes. It is then poured into tin containers, which are hermetically sealed and sterilised at 230° F. for thirty minutes.

Other varieties of cheese are treated in a very similar manner. In the case of Gruyère cheese, some 2 per cent. of Neufchatel cheese, 10 per cent. of water, 3 per cent. of sodium citrate, and a small quantity of salt are
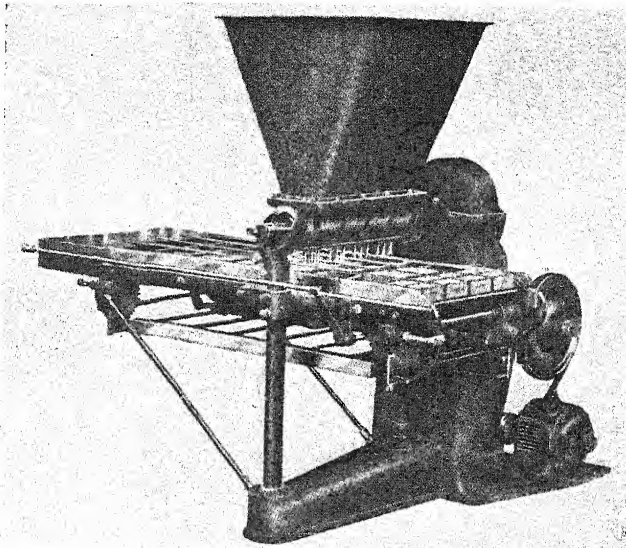
By courtesy of Sutherland Thomson & Co.

FIG. 56—"Kustner" Cheese Filling Machine

added, the mixture being heated to 170° F. and held at this temperature for thirty minutes. The treatment of Camembert cheese is almost identical, except that 4 per cent. of Cheshire or Cheddar cheese previously ground, and 0·1 per cent. of sodium citrate are added. No water is required in this process. Camembert cheese is much improved by this treatment, as normally it possesses poor keeping qualities.
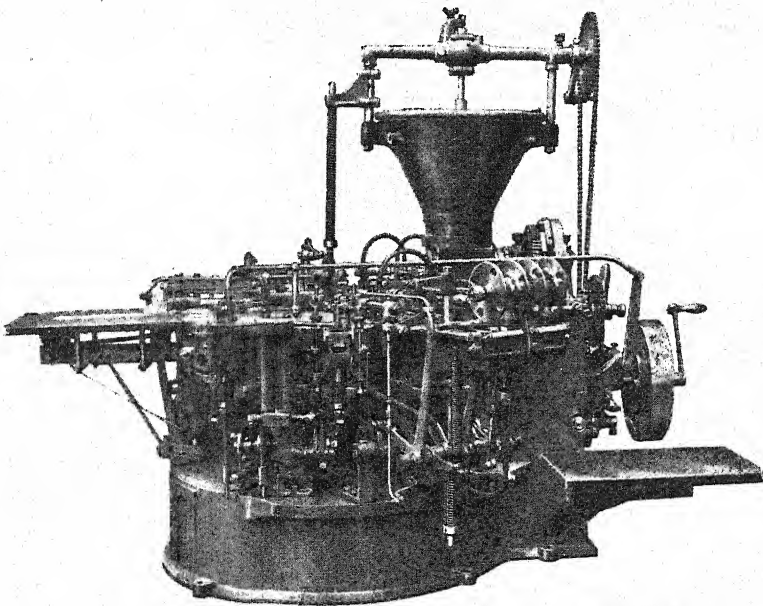
By courtesy of Sutherland Thomson & Co.

FIG. 57—"Kustner" Automatic Filling and Packing Machine for Cheese Portions

Crustless cheese is wrapped in tinfoil, and for this reason there is considerable risk of metallic contamination, as the foil is made from a mixture of tin and antimony. . Many of the tinfoils now used for wrapping crustless cheese are given a coating of shellac to protect the cheese from the action of the tin. This type of contamination could also easily be avoided if some form of tissue paper were used for wrapping the cheese prior to the fixing of the external cover of tinfoil. At Hammersmith in 1932 a number of soft cheeses wrapped in tinfoil were found to be blackened and mouldy. They were seized and destroyed and a sample purchased under the Food and Drugs (Adulteration) Act, 1928, which was then in force. The portions were found to contain 14 grains of tin per pound. Proceedings were taken and resulted in a conviction. The Medical Officer
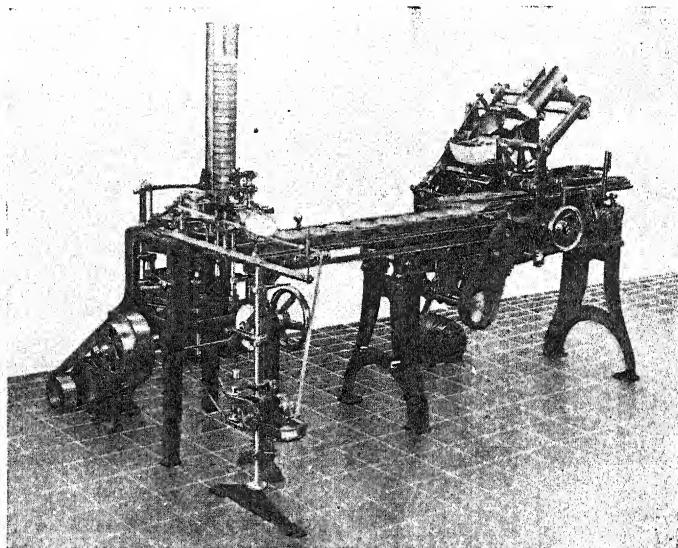
By courtesy of Sutherland Thomson & Co.

FIG. 58—"Kustner" Bandrolling and Labelling Machine for Round Cheese Boxes

of Health for Lambeth has reported that soft, foil-wrapped cheese has been found to contain 5·68 grains of tin per pound. It is probable that, after a period of storage, the quantity of tin absorbed by the cheese is quite high. Two grains per pound are unusual and unnecessary, and there should be even less present.

Dehydrated Cheese

Experiments have been carried out in the United States of America by the Bureau of Dairy Industry with a view to reducing the moisture content of cheese. A method has been devised in which this has been reduced to about 2·5 per cent. of the whole, and if this process could be carried out on a commercial scale a saving of weight amounting to about 35 per cent. would be effected. The product is in the form of flakes which can be compressed into blocks and the underlying idea of the experiments was to save shipping space during the War.

Canned Cheese

A method of canning natural cheese has been devised by the Metal Box

Company, Ltd., which offers an excellent method of packing, reduces labour costs and losses due to shrinkage.

The cheese is placed in the can straight from the press and ripens in its own gas. Tests have been carried out with the Cheddar variety with satisfactory results, and it would appear possible to can other types of cheese in a similar fashion.

The can employed is fitted with a non-return valve which has a thin rubber diaphragm fixed into a small tinplate cap, which is pressed into a dome in the lid or side of the can. The cap contains an aperture $\frac{1}{16}$ th of an inch in diameter which relieves any internal pressure without admitting air. Any accumulation of gas inside the can causes the rubber diaphragm to rise and allow the gas to escape. If there is no pressure inside the can, the diaphragm keeps the aperture in the lid securely closed. Oxidation cannot occur or mould spores form, evaporation and shrinkage are prevented, and a fine, rindless cheese is provided.

The cheese is wrapped in suitable transparent paper before it is placed in the can, which is at once sealed by means of a double seaming operation. Cans are made in all sizes from 1 lb. to 70 lb. and these are well lacquered. A cheese of a uniformly high standard may be obtained, as by regulating the storage temperature, the quality and flavour may be controlled within close limits. Cheese when packed in this manner can be kept for long periods and there is no waste.

Various types of cheese have been canned in the United States of America, such cheeses being cured before they are packed. Packing takes place under a vacuum in the presence a small amount of magnesium or calcium dioxide. These chemicals are used to take care of the gas evolved during the ripening process.

Abnormalities in Cheese

Cheese is particularly liable to abnormalities in its substance, such defects originating from the following sources:

(1) Raw milk of abnormal composition.
(2) Faulty methods of manufacture.
(3) Bacterial action.

It is found in practice that these causes are closely allied, rendering it a difficult matter properly to classify the defects into their appropriate sections. If the milk and cheese are correctly treated, the development of harmful organisms may be avoided, while, if the methods used are inefficient, the growth of such organisms will be encouraged, even if milk of the highest quality is used.

Milk sometimes curdles badly if it contains colostrum or if it is the product of cows reaching the end of their lactation periods. Curd obtained from such milk does not dry readily, and the resultant cheese will become spongy, although the milk may be bacteriologically pure. Sponginess is due not only to the presence of gas-producing organisms in the milk, but also to an excess of lactose in the curd. Gas-producing organisms, such as *Aerogenes mastitis*, may be present in the milk as it leaves the udder, but mainly owe their presence to gastric affections in the animals and dirty methods of milking. If the digestive disorders in the animals are acute, gas-producing organisms will be present in the fæces in large numbers,

and are almost certain to obtain entrance to the milk. Carbon dioxide and hydrogen are the principal gases formed. Carbon dioxide is extremely objectionable, as the moisture present in the cheese absorbs large quantities of this gas before any sponginess is apparent. Hydrogen, on the other hand, is not absorbed by water to any great extent, and organisms producing hydrogen therefore do less harm. In particular, butyric-acid organisms may cause a cheese to become spongy within a few days. Colon organisms also produce hydrogen and acid, due to the fermentation of the milk sugar. Fermenting yeasts also cause this defect.

If the curd is too acid, or if it has been allowed to become dry by overscalding, it becomes crisp and is easily cracked or broken into pieces if roughly handled. This is particularly the case if excess of gas is produced. Overdrying or the addition of excessive salt will produce a hard curd which will crack easily. The rind will also crack if a large quantity of whey collects underneath. This often occurs through excessive pressure being applied too quickly, the outer layer of cheese becoming too compact before all the whey has been expelled. Slimy whey will also cause this defect. If cheeses are too damp, but not over-acid, they may become liquefied, particularly if *Streptococcus liquefaciens* is abundant. This organism peptonises the curd and produces a bitter taste.

Colour defects are important, particularly as cheese is stored for ripening periods, during which time such defects have ample opportunity to develop. Cheese, on being cut, occasionally exhibits light patches within the substance, due to the presence of iron or copper salts. These salts may gain entrance from the water supply, following the use of direct steam for heating the milk, or from the cheese vat, if this is constructed of copper or copper-lined. If the defect is due to the presence of ferrous salts, the exposure of the affected surface to the air will result in the disappearance of the colour. If the discoloration is due to the presence of copper salts, the outer portions of the cheese will be most affected, while exposure to the air will assist the colour to develop. Colonies of chromogenic organisms sometimes develop in the cheese and form minute coloured spots throughout its substance. Blue spots in Edam cheese are caused by the presence of *Bacillus cyaneofuscus*, while red or brown spots in Swiss cheese are caused by chromogenic, propionic-acid bacteria. Blue mould is produced by *Aspergillus glaucus*.

Cheddar cheese suffers on occasion from the presence of rust or red spots. These are caused by a pigment-producing organism named *Lactobacillus rudensis*. Other types of hard-pressed cheeses also suffer from a similar type of discoloration, believed to be due to organisms of the coli group or to the presence of moulds, such as the genus *Oidium*. Red mould is also produced by *Sporendonema caseii*. Roquefort and similar cheeses occasionally exhibit yellow colorations, which are presumed to be due to the presence of *Oidium lactis* or micrococci. Chromogenic organisms sometimes produce a red coloration immediately underlying the rind. Such organisms are *Micrococcus chromoflavus*, *Bacterium casei fusci*, and *Bacillus firmitatis*. One case of curd infection following precipitation at high temperature has been reported. After twenty-four hours storage the whole surface turned red and this was found to be due to the presence of *Rhodococcus roseus*. Yellow and brown discolorations of the rind are due to the presence of *Micrococcus flavius*, an organism commonly present in

the air. Many moulds, such as *Penicillium casei*, *Cladosporium herbarum*, *Monilia negra*, and *Oidium aurantiacum*, produce surface colorations. Some of these moulds penetrate the rind and render the surface uneven. Chalky whiteness in cheese is produced by the mould *Oospora caseovorous*.

Defects in taste and smell are reasonably common in cheese. Many of these originate in the feeding-stuffs supplied to the cattle, and generally disappear in time. *Bitter or tallowy tastes* are most unsatisfactory. These are chiefly due to the by-products of bacterial activity introduced in excess, as a result of careless handling or faults in manufacture. These bacteria are normally held in check by the lactic-acid organisms, but this restraint is sometimes withdrawn or decreased. The organisms which are the cause of *sponginess* sometimes give rise to bitter tastes. Bitter or tallowy tastes often occur when fresh cheeses are kept in an atmosphere which is too cold or too damp. Many of the chromogenic organisms produce bitter tastes. *Streptococcus liquefaciens* and *Torula amara* are examples of this, although these organisms may disappear as the ripening period advances. Lactic-acid bacilli are also sometimes the cause of bitterness. A tallowy taste is occasionally observed in rich cheeses, this being due to the same organisms which are the cause of tallowy flavours in milk and butter. The exposure of cheese to excessive sunlight may oxidise the fat and so cause a tallowy taste, while the presence of copper salts or carbonic acid may be a contributory cause of this taint. A *taste of cabbage* is produced in some of the French soft cheeses by the organism *Penicillium trevicaule*.

Manufacturing defects are also common. Cheddar cheeses are sometimes *overcooked* or *overdrained*, these defects resulting in a dead flavour, or dry, fatless texture. Such cheeses may also be *sweet, tough, over-acid*, or *oversalted* because of faulty methods of manufacture. Gorgonzola and Roquefort cheeses are sometimes discoloured owing to contamination by bacteria following packing operations. Gorgonzola cheeses may also be bitter, this being due to the presence of liquefying organisms or to the ripening of the cheeses at too low a temperature. Over-acidity is also common. All defects due to faults occurring during manufacture may be avoided if careful methods and strict cleanliness are observed and continuously maintained. As in the case of other manufacturing processes, strict scientific control is essential throughout the process.

Cheese mites and *cheese flies* are also a serious nuisance to the producers of cheese. The cheese fly is a small black insect which lays its eggs in the cracks of cheese. These hatch out in three days and become adult flies in three to four weeks. The cheese mite is allied to the spider family, its eggs being extremely resistant to external conditions, rendering their destruction difficult. They hatch out in ten to twelve days and pass through a first and second nymph stage before the adult stage is finally reached. These insects are extremely harmful to cheese. They are capable of rapid reproduction and eat into cheese at an almost incredible rate. To prevent defects from organisms and insects, it is essential that the interior of the ripening room and its fittings should be thoroughly disinfected. Two per cent. formaldehyde or a 2 per cent. solution of ammonium bifluoride are very useful disinfectants for woodwork, while the walls should be treated with limewash to which 2 per cent. of copper sulphate has been added. Only the strictest cleanliness will prevent the development of unwanted organisms or parasites.

Bacteria and Moulds in Cheese

Cheese contains innumerable bacteria or moulds of various types, which may be divided into two main groups:

(1) Non-pathogenic.

(2) Pathogenic.

(1) **Non-pathogenic Organisms.**—The manufacture and ripening of cheese are dependent at various stages upon the growth and multiplication of bacteria and moulds, of which the lactic-acid group of organisms predominates. The importance of lactic-acid bacteria is based upon the following facts:

(a) They cause the development of acidity during the ripening of the milk.

(b) This acidity activates the pepsin of the rennet and favours coagulation.

(c) The co-operation of the lactic-acid organisms with the pepsin of the rennet assists digestion of the protein.

(d) The acids formed check the growth of putrefactive bacteria which, if allowed to develop, would decompose the casein and render the cheese non-edible.

(e) These organisms are chiefly responsible for the flavours which develop in cheese.

Different varieties of cheeses possess varying types of organisms, and it is necessary to give brief consideration to the special types of organisms present in each variety. For this purpose, the cheeses may be divided into two groups:

(a) Hard Cheeses.

(b) Soft Cheeses.

(a) *Hard Cheeses.*—This class of cheese is by far the most common, the bacterial content being fairly simple. Hard cheeses may be subdivided into three classes:

(i) Lactic-acid Cheeses.

(ii) Mould Cheeses.

(iii) Fermented Cheeses.

(i) LACTIC-ACID CHEESES.—Cheddar cheese is one of the best-known representatives of this class. Cheeses of this and similar types are manufactured from milk ripened with lactic-acid bacteria, such organisms functioning throughout the processes of manufacture and ripening. Most of the other organisms initially present are suppressed by the acidity which develops. The lactic-acid organisms comprise both streptococci and lactic-acid bacilli. These two types of lactic-acid organisms are also found in Danish cheese, the milk used in the manufacture of this type being inoculated by the addition of butter-milk. Edam cheese is manufactured from milk ripened by lactic-acid "starter." Other bacteria play a minor part in its ripening, which is due to the chemical changes brought about by the ferments of rennet. Gouda cheese, which is made from fresh milk, contains few lactic-acid organisms, and ripens with the assistance of *Tetracoccus liquefaciens*, which produces its characteristic flavour. Owing to the absence of large numbers of lactic-acid organisms, this organism has ample opportunity for development.

(ii) MOULD CHEESES.—Mould cheeses are initially ripened by lactic-acid organisms, but, in the later stages of ripening, moulds develop within the cheeses. With certain types of cheeses, moulds are inoculated into the

substance, such cheeses ripening much earlier than is the case when a chance infection of moulds is relied upon. The principal type of mould is the *Penicillium roqueforti*, as the absence of oxygen prevents many other moulds from developing. *Penicillium roqueforti* attacks both the fat and the protein in the cheese, but it must be remembered that the hydrolysis of the fat is responsible for the characteristic taste and odour of this class of cheese. Roquefort cheese possesses a mottled appearance, due to the growth of this mould. To assist this growth, cheeses are pierced, but before and after this operation takes place, the external surfaces are cleaned to prevent the entrance of any unwanted organisms. Gorgonzola cheese is ripened by this mould after the milk has received a preliminary ripening by lactic-acid organisms. The cheeses are not specially inoculated, the surroundings in which the cheeses are usually made containing a plentiful supply of the mould in the air and dust. *Oidium lactis* and other *Penicillium* moulds produce the bluish-green veins so characteristic of the mould cheeses. Stilton cheeses are ripened by the mould *Penicillium glaucum*, but are not inoculated or pierced. The organisms obtain entrance by means of fissures in the rind, but develop very slowly.

(iii) FERMENTED CHEESES.—Swiss cheeses are ripened in a different manner from the two groups already mentioned. There is little lactic acid in the curd before coagulation, as fresh milk is used, while the small quantity of salt utilised allows the various types of bacteria to develop. The proteolytic changes are caused by lactic-acid organisms, but the flavour is due to lactic-acid bacilli of the *Bacillus bulgaricus* group. The characteristic "eyes" are formed following fermentation of the by-products of the lactic-acid organisms by proprionic-acid bacteria. The formation of "eyes" can be prevented by the addition of an increased quantity of salt. Organisms of the *Bacillus bulgaricus* group are plentiful in rennet. The principal member of this group is the *Thermobacterium helveticum*.

(b) *Soft Cheeses*.—These may be divided into two groups, as follows:
(i) "Smeared" Cheeses.
(ii) "Mouldy" Cheeses.

(i) "SMEARED" CHEESES.—In this type, the surface growth of mould is suppressed by wiping the external surfaces with a damp cloth. Limburg cheese might be taken as representative of this group. This cheese ripens in two different ways. The internal ripening is caused by rennet and lactic-acid bacteria, while there is an external ripening due to the growth of moulds upon the exterior. The pungent odour associated with this variety of cheese is due to the external growth of moulds. These surface moulds are formed by a peptonising tetracoccus and by *Bacillus casei Limburgensis*. This latter organism oxidises the lactic acid. It does not attack the protein, living upon the amino-acids produced by the peptonising tetracoccus. Decomposition is thus carried a stage farther than in other types of cheeses. Ammonia is produced, and this spreads inwards, neutralising the lactic acid of the interior and converting the casein into soluble ammonium caseinate, thus permitting the development of other bacteria, which cause further decomposition.

(ii) "MOULDY" CHEESES.—With this class of cheese, the surface growth of moulds is encouraged by keeping the cheeses dry and providing free access of air. Camembert cheese is representative of this type. The

milk used during manufacture is ripened by lactic-acid organisms, but, owing to the method of manufacture, large quantities of whey are retained within the curd. Because of the activity of the lactic-acid organisms, acidity is high. This protects the interior from proteolytic organisms. Many kinds of bacteria, yeasts, and moulds settle upon the external surfaces and grow inwards, neutralising the acidity and changing the texture of the cheese. The *Oidium* type, principally *Oidium lactis*, is the first to appear, but when the surfaces become drier, the mould *Penicillium camemberti* makes its appearance, this mould being particularly active in reducing acidity. These moulds also produce enzymes which digest the curd, producing conditions favourable for the proteolytic organisms such as *Bacillus casei Limburgensis* which are already present. Because of the reduction of acidity, putrefactive organisms may show great activity and cause the cheese to decompose shortly after it has become ripe. In this country, the milk for the manufacture of this type of cheese is inoculated with the necessary organisms in the manner described on page 208.

(2) **Pathogenic Bacteria.**—A considerable proportion of all cheese is manufactured from raw milk, and may therefore contain any of the pathogenic organisms present in the original liquid. This is particularly so in the case of cheeses which are consumed in the fresh state. The most important pathogenic organism found in cheese is the *Mycobacterium tuberculosis*. This organism has been isolated from a considerable percentage of farm-house cheeses. In cheeses of the Cheddar type, the *Mycobacterium tuberculosis* may remain virulent for seventy days, although in Swiss cheeses they have generally disappeared by the fortieth day after manufacture. The presence of *hæmolytic streptococci* and *Brucella abortus* should also not be overlooked in cheese, as such organisms may be present in the original milk supply. *Brucella melitensis* may be found in unripened cheeses manufactured from goat's milk. Because of their unaccustomed environment, it is doubtful if these organisms retain their virulence for lengthy periods.

The aforementioned types of organisms are those most commonly found in milk as obtained from the cow, but infection of cheese by pathogenic organisms may also occur during manufacture. *Bacillus typhosus* has been isolated, but does not survive in cheese for more than twenty-five days, probably disappearing much more quickly. The period of its survival probably depends upon the type of cheese in which it is present. *Corynebacterium diphtheriæ* does not survive in cheese for more than fourteen days, while *Vibrio choleræ* is reported to die out in two or three days.

The fact that such organisms may be present in cheese, particularly of the unripened varieties, is a sound argument why milk intended for cheese-making should be pasteurised wherever possible before any "starter" is added. Indeed, many American States possess regulations which require that cheeses of the hard variety shall be made from pasteurised milk, be pasteurised after production or, if manufactured from raw milk, shall be held for sixty days before they are sold to the consumer. A sixty-day storage period appears to provide complete protection from a public health standpoint.

Bacteriological Control

As already indicated, cheese contains very numerous bacteria, together with yeasts and moulds of various types. Cheese when obtained for bacteriological examination should be sampled by means of a sterile knife or trier. If removed with a knife, a triangular piece should be cut, starting from the centre of the cheese. The sample should be placed in a sterile glass jar, which should be sealed and removed to the laboratory as quickly as possible.

The usual examinations carried out are:

(1) Determination of Specific Organisms Present.
(2) Investigation for presence of Tubercle Bacilli.
(3) Mould and Yeast Count.
(4) Bacterial Count.

(1) **Determination of Specific Organisms Present.**—It is sometimes necessary to determine the numbers and types of bacteria present in samples of cheese. The procedure is carried out in the following manner: Five grams of cheese, removed from the centre of the cheese, are weighed into a sterile vessel. The cheese is then placed in a sterile mortar and thoroughly ground with sterile sand. The ground cheese is transferred to a flask containing 95 mls. of sterile water. A portion of this water is used for washing out the mortar. The flask is thoroughly shaken, following which a series of dilutions is made and plates poured, as described on pages 53 and 54. The bacteria are cultivated on nutrient agar media, the plates being incubated at 25° C. After the incubation period has ended, the number of colonies may be counted. The variety of organisms present is usually exceedingly complex, and, while it may be impossible to identify all the colonies discovered, some idea of the predominance of certain types may be obtained. This is carried out by inoculating a number of colonies into tubes of litmus milk or nutrient gelatine. Those organisms which ferment lactose will cause the milk to clot, while the gelatine will be liquefied by the proteolytic bacteria.

(2) **Investigation for the Presence of Tubercle Bacilli.**—The determination of the presence of tubercle bacilli in a sample of cheese is made in a similar manner to that already set out on page 98, but the production of a satisfactory emulsion for injection purposes is difficult.

(3) **Mould and Yeast Count.**—The cheese is prepared, the dilutions made, and the plates poured and incubated in a similar manner to that described for the determination of the presence of bacteria (see page 163), except that the media used is glucose or beer wort agar. After incubation, the moulds and yeasts are counted separately, the two counts being added together to give the final total.

(4) **Bacterial Count.**—One gram of the sample is emulsified in sterile water in a sterile mortar. This emulsion is diluted up to 100 mls. and the examination is then carried out in the manner described on page 53.

Chemical Examination

The method of sampling cheeses for chemical examination varies according to the type of cheese being investigated. When the sample is to be obtained from one of the hard varieties, a portion should be removed from the side and one from the top centre of each cheese, by means of

a trier. The samples should be placed in a sealed jar. With soft cheeses, a knife may be used to remove a sufficiently large portion. If the sample is obtained in the operation of the Food and Drugs Act, 1938, ¾ lb. of cheese should be purchased, this being divided into three equal portions.

The usual chemical examinations made are for:

(1) Fat Content.
(2) Moisture Content.
(3) Mineral Salts.
(4) Protein Content.
(5) Starch Percentage.
(6) Resazurin Test.
(7) Phosphatase Test.

The examination of both hard-pressed and soft varieties of cheese is carried out in an identical manner.

(1) **Fat Content.**—The fat content may be calculated in a variety of ways, of which the following are reasonably simple:

(a) Gerber Test.
(b) Roese-Gottlieb Method.

(a) *Gerber Test.*—One gram of cheese shavings is placed in a weighing funnel. A Gerber butyrometer is prepared as mentioned on page 164 (Gerber test for fat percentage in butter). The subsequent procedure and formula are the same, the cheese shavings being transferred to the butyrometer by means of a camel-hair brush.

(b) *Roese-Gottlieb Method.*—The sample is cut into small portions and thoroughly mixed. One gram of cheese is weighed directly into the extraction flask and 8 mls. of hot distilled water added. The remainder of the test is carried out in a similar manner to that already set out on page 100.

(2) **Moisture Content.**—Five grams of cheese are cut into small pieces, approximately the size of wheat grains. These are placed in a jacketed cup and dried at a temperature of 100° C. When a constant weight is obtained, the percentage of moisture is found by dividing the loss in weight by the original weight. This, multiplied by 100, gives the desired percentage.

(3) **Mineral Salts.**—The residue which remains, following the examination for percentage of moisture, is carefully incinerated at low red heat, the residue being weighed and calculated to a percentage.

(4) **Protein Content.**—The percentage of proteins is obtained by multiplying the percentage of nitrogen as determined by Kjeldahl's process, by 6·38 (for details of this process, see pages 57 and 58).

(5) **Starch Percentage.**—A small portion of the sample from which the fat has been extracted is boiled with water and filtered. A few drops of iodine solution are then added to the filtrate. If starch is present, a blue colour will become visible.

(6) **Resazurin Test.**—As already mentioned on page 59, with reference to milk received for ice-cream manufacture, this test should be applied to incoming milk on receipt from the farms before it is made up into cheese.

(7) **Phosphatase Test.**—Cheese which has been made from pasteurised milk will, if the processing has been efficient, react to this test. Twenty grams of cheese are triturated with 20 mls. of buffer-substrate and 20 mls. of water. One millilitre of this mixture is submitted to the test in the usual way, as set out on page 59.

LEGISLATIVE CONTROL

Cheese being classified as a foodstuff, the legislation governing food production and distribution applies to its manufacture and sale. A summary of the Acts and Orders which apply is set out below, together with the relevant Sections or Articles.

Act or Order	*Section or Article*
Public Health (Preservatives, etc., in Food) Regulations, 1925	4, 6, 11
Factories Act, 1937	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 41, 42, 43, 44, 45
Public Health (Imported Food) Regulations, 1937	6, 7, 8, 9
Food and Drugs Act, 1938 . . .	1, 2, 3, 13, 17, 18, 68, 69, 70
Cheese (Control and Maximum Prices) Order, 1943	Whole Order

Public Health (Preservatives, etc., in Food) Regulations, 1925

The addition of preservatives to home-produced or imported cheese is prohibited. Articles 4, 6, and 11, which deal with this matter are set out on pages 60 and 104.

Factories Act, 1937

The Sections of this Act which apply to all food-preparing premises other than those whose sanitary condition is governed by Section 13 of the Food and Drugs Act, 1938. Details of these Sections are set out on pages 62 to 64.

Public Health (Imported Food) Regulations, 1937

The relevant Articles applying to the importation of cheese are similar to those which apply to other foodstuffs and further details are to be found on page 174.

Food and Drugs Act, 1938.

Sections 1 to 3, 13, 17 to 18, and 68 to 70 have already been detailed on pages 64 to 67. The definitions "dairy" and "dairyman" are given on page 108, while below is given the definition of "cheese" and a portion of Section 68 which applies to this substance.

Definition: "Cheese" means the substance usually known as cheese, containing no fat other than fat derived from milk.

Powers of Sampling.—Section 68. (3) A sampling officer may take samples of—

(a) any . . . cheese or substances resembling . . . or cheese, exposed for sale and not marked in the manner in which . . . is required to be marked under this Act.

The Cheese (Control and Maximum Prices) Order, 1943

This Order prohibits the manufacture of home-produced or processed cheese except under licence, and record of purchases, sales, or stocks have to be kept by wholesale traders dealing in specified cheese, soft cheese, or curd cheese. As mentioned in regard to butter on page 178, the production of an analyst's certificate is evidence as to examination.

Definitions: "Home-produced cheese" means any cheese produced in the United Kingdom but not including soft or curd cheese or processed cheese.

"Processed Cheese" means cheese which after manufacture has been heated and to which an emulsifying agent has been added.

"Soft Cheese" or "Curd Cheese" means cheese, the moisture content of which exceeds 55 per cent.

Whey

Whey is the only by-product of cheese manufacture, and is produced in enormous quantities annually. While a considerable proportion of the output is utilised in various ways, it has been estimated that at least 40,000,000 gallons are wasted each year and it has been necessary in many cases to install and maintain costly treatment plants at creameries to prevent contamination of adjoining streams. The loss has been stated to be in the neighbourhood of £1,000,000, and it appears ridiculous that milk should be produced so that subsequently half its nutritive value is wasted. Whey from cheese factories may be returned to the farmer for pig feeding, evaporated or dried, made into whey cheese as is the practice in some foreign countries, the lactose it contains may be extracted, or the butter-fat still remaining in the whey may be removed by separation and manufactured into butter. If whey is returned to the producer after separation has been completed, it should be either pasteurised or sterilised before it leaves the factory. The average composition of whey is:

			Per cent.
Water			93·00
Total Solids	(a) Fat	0·38	
	(b) Casein, Albumin	0·86	7·00
	(c) Lactose	5·00	
	(d) Ash	0·76	
			100·00

If the manufacturing methods are satisfactory and well-managed, the whey should possess a greenish colour. White-coloured whey denotes the fact that the curd has been roughly handled during cutting operations. The whey from the vats and the presses should, when discharged, have the appearance of clear brine.

Whey contains sixteen times as much lactose and twice as much albumin as butter, while further, since it contains only a small quantity of fat, it does not sour so quickly. Whey is invaluable for the feeding of animals, possessing as it does a definite food value and a high vitamin content. It is particularly rich in calcium and vitamin B_2 and contains nearly half the solids present in the original milk. The Lancashire County Council have demonstrated at their Experimental Farm at Hutton that 12 lb. of whey are equal in feeding value to 1 lb. of meal in the feeding of pigs. They also reported that pigs fed in this manner became heavier and firmer in flesh, which, moreover, possessed a better and more even distribution of lean and fat than when fed on new milk.

Whey is often used for bread-making, being very economical when employed in lieu of milk. After the whey has been pasteurised, it should be water-cooled, as brine-cooled whey prevents the yeast working in the bread. Flash pasteurisation is suitable for this purpose. In Germany, during the War, whey was condensed into a syrup for use in bakeries and for mixing with animal feeding stuffs.

In addition to these uses, many cheese factories separate the remaining fat from the whey and use it for the manufacture of *whey butter*. This butter is of excellent quality (for method of manufacture, see pages 166 and 167). The method of drying whey is described in Chapter VIII.

CHAPTER V

CONDENSED MILK

Introductory

A CONSIDERABLE proportion of the milk produced annually in this country is concentrated in various ways in order to preserve it for lengthy periods, while large quantities of the condensed product are also imported from abroad. The trade in concentrated milk of one kind or another is thus large, and is increasing annually. The concentration of milk possesses several advantages over other methods of manufacture. The production of cheese or butter entails the loss of a large proportion of the constituents of the milk in the form of whey or as separated milk. On the other hand, concentrated milk contains the whole of the original constituents of the milk in small bulk, with the added advantage of prolonged keeping qualities.

It is only within the last century that milk has been preserved in a manner which permits its reconstitution to a liquid state. Researches were carried out both in this country and in France at the beginning of the nineteenth century in order to discover a method of preserving milk in concentrated form. Before 1850, Appert had produced milk in tablet form, De Heine had devised a method for concentrating milk and preserving it by the addition of sugar, while the vacuum pan had been patented by Howard and had been adapted by Newton for use with milk. The condensed milk industry really commenced when Borden, in 1856, patented a process for the production of sweetened condensed milk, and this industry developed rapidly during the latter half of the nineteenth century.

A considerable increase in the home production of concentrated milk has taken place since the inception of the Milk Marketing Board, with the result that, until the War, smaller quantities were being imported from abroad than was formerly the case.

Milk may be concentrated in either of the following ways:

(1) By condensation (Condensed Milk).
(2) By drying (Dried Milk).

Condensed milk may again be subdivided into the following types:

(1) Sweetened whole milk.
(2) Sweetened skimmed milk.
(3) Unsweetened whole milk.
(4) Unsweetened skimmed milk.

Unsweetened condensed milk is generally termed *evaporated milk*, and this type, together with dried milk, will be discussed in subsequent chapters. The purpose of the present chapter is thus to consider the manufacture of *sweetened* condensed milk from either whole or skimmed milk. The manufacturing methods are similar in each case.

Sweetened condensed milk is a viscous fluid. Approximately $1\frac{3}{4}$ lb. of fresh milk will yield 1 lb. of condensed milk. It will thus be seen that, during the processing, the milk is condensed to some one-half of its original volume. Sugar is added as a preservative, some brands containing large

quantities of this substance. Both whole and skimmed milk may be sweetened and condensed, but condensed skimmed milk is poor in fat and possesses little food value. It is marketed either in closed wooden barrels or in sealed cans, the latter form being the usual vehicle in which it is sold to the consumer.

Composition

The composition of sweetened condensed milk varies in accordance with the type of milk used during manufacture. Average analyses of sweetened whole and skimmed condensed milk are set out below:

	Sweetened Whole Milk	Sweetened Skimmed Milk
Total Milk Solids	75·6	72·0
Fat	9·1	0·4
Mineral Matter	1·9	2·2
Protein	8·4	10·0
Lactose	12·2	14·4
Cane Sugar	44·0	45·0
Water	24·4	28·0

Condensed milk, in a similar manner to fresh milk, must comply with certain standards as regards fat content and percentage of total solids, this standard varying according to the country of origin. Below are given the standards for this country and those in force in the United States of America.

	Percentage of Milk Fat	Total Milk Solids
(1) *Great Britain*		
(a) Full Cream, Sweetened	9·0	31·0
(b) Skimmed, Sweetened	—	26·0
(2) *United States of America*		
(a) Full Cream, Sweetened	8·0	28·0
(b) Skimmed, Sweetened	—	24·0

It will be observed from the foregoing figures that the standard for sweetened full-cream condensed milk in this country is appreciably higher than that in force in the United States of America. A higher ratio of condensation is therefore necessary, as more moisture has to be removed. The final product in this country is much more viscous than that produced in America, and on this score is liable to a defect known as "progressive thickening" (see page 249). The technique and practice of condensation in the United States are entirely different from that obtaining in this country, while it has even been found that organisms which are capable of development in one brand of condensed milk do not grow in another type, since the increased viscosity limits the growth of certain of the species.

Food Value

Condensed milk is a convenient product for household use, possessing, as it does, satisfactory keeping qualities. Because of its small bulk and keeping qualities, it is particularly useful on board ship and in the tropics. In the household, it is often used for infant feeding and for the preparation of tea, coffee, and puddings. It is easily reconstructed by dilution with water to the equivalent concentration of raw milk. This type of milk is also extensively used by the chocolate and confectionery trades.

In Great Britain, skimmed condensed milk had to bear the caption "*Unfit for Babies*," by reason of the deficiency in milk-fat present. In 1943, this caption was amended to "*Not to be used for Babies*." The nutritive value of the fat, when present, depends in turn upon its energy-producing value and upon the presence of the two fat-soluble vitamins A and D, which are essential to normal growth and health. The heat treatment applied during the processing is unlikely to cause any appreciable diminution in the food value of the lactose, although, if processing is faulty because of excessive temperature, caramelisation may take place. This change of flavour is often submerged in the sweetness due to the added cane sugar. So great a quantity of cane-sugar is often added to sweetened condensed milk that it becomes necessary for the consumer to dilute the article in order to minimise this sweetness. If this is done, the food value of the product is reduced, as there is then a deficiency in fat, vitamins, and salts.

The proteins of milk undergo little change during the processing, unless the milk is preheated at an excessive temperature, when they may coagulate. There is little evidence to show that such coagulation exerts any detrimental effect upon the product or affects its digestibility in any way. Milk is frequently heated to pasteurisation temperatures prior to the condensing process, and is, in fact, often pasteurised in a similar manner to milk; while in some instances, even higher temperatures are used. The calcium and phosphorus salts are particularly affected by this heating process, although the alterations in nutritional value as a result are probably negligible.

The effect of the process upon the vitamin content of the finished product is exceedingly important, for three reasons:

(1) The vitamins are present in very small quantities.
(2) Some of the vitamins are susceptible to the effects of heat and of oxidation.
(3) Vitamins are vitally important constituents of the diets of infants and young children.

Numerous investigations have been made into the effect of heat upon the vitamin content of milk. A summary of the generally accepted properties of the individual vitamins as regards heat treatment and oxidation are set out below:

Vitamin A.—This vitamin is stable as regards heat, and will survive a temperature of 248° F. for twelve hours. It is, however, very susceptible to oxidation, and the effect of the processing upon the destruction of this vitamin depends upon the extent to which oxygen is present, and not upon the temperature to which the milk is subjected or the duration of the heating.

Vitamin B_1.—This vitamin possesses considerable resistance to heat, although it is not so resistant as vitamin B_2. It is also very resistant to oxidation. Destruction is slow at a temperature of 212° F., but is rapid at 248° F.

Vitamin B_2.—This is highly stable in the presence of heat, and will resist a temperature of 248° F. for several hours. It is therefore not likely to be affected by the processing.

Vitamin C.—Oxidation exercises a detrimental effect upon this vitamin, as it is exceedingly susceptible. The effect of heat depends upon the presence of oxidising substances. The presence of dissolved oxygen in milk is assumed to be sufficient to lead to a partial destruction of this vitamin when milk is heated up to and above the normal pasteurising temperature.

Vitamin D.—This vitamin is extremely stable in the presence both of heat and of oxidation and is unaffected by the processing.

Vitamin E.—This is also extremely stable in the presence of heat and of oxidation.

From the foregoing summary it will be observed that, so far as condensing is concerned, the greatest risk as regards the diminution of the vitamin content lies in the destruction of vitamins A and C, which are easily affected by oxidation. These vitamins are essential requirements in the normal diet of young persons, and for this reason condensed milk cannot be described as a suitable diet for children unless other foodstuffs containing a sufficiency of such vitamins are added to the dietary.

No information appears to be available as to the general nutritive value of condensed milk used as a complete article of diet, when compared with raw liquid milk. Such an investigation might profitably be undertaken upon a suitable scale and at an early date.

Condensed Milk and Disease

No definite outbreaks of disease have been traced to the consumption of condensed milk.

Effect of Heat upon Milk

It is the practice in some condenseries to preheat the milk used to a high temperature before it is condensed, but, as experiments have shown that pasteurisation of the article at a temperature of 145° F. for thirty minutes or at 162° F. for thirty seconds is a suitable means of forewarming the milk, this is now becoming a popular practice. Preheating is normally carried out with tubular heaters. Although some changes are bound to occur under such conditions, the food value of the milk is only slightly altered.

Milk undergoes certain changes when heat is applied, such changes being influenced by two factors, as follows:

(1) The time during which the milk is exposed to the heating agent.

(2) The temperature reached during the process.

Milk expands on heating in a similar manner to other liquids, the co-efficient of expansion being greater than that of water. The changes which occur may be considered under two headings:

(1) Changes in Bacterial Content.

(2) Chemical Changes.

(1) **Changes in Bacterial Content.**—The temperatures normally employed in the manufacture of condensed milk are not usually excessive, but are such as will materially affect the bacterial flora of the milk. All pathogenic organisms present in the milk will be destroyed if the raw milk is efficiently pasteurised during the preheating process. With regard to non-pathogenic organisms, the following conclusions may be taken as representative of the consensus of modern opinion:

(a) The reduction in the numbers of organisms present in the milk does not wholly depend upon the apparatus used, being also affected by the types of organisms present.

(b) Milk with an initial low bacterial count does not show such a large percentage reduction as milk which possesses a high initial count.

(c) Laboratory pasteurisation will reduce the bacterial content by as much as 99 per cent., but such a high percentage reduction is not possible upon a commercial scale.

(d) An increase in the number of bacteria present occurs during the subsequent handling of the milk.

It can be categorically stated that the majority of lactic-acid organisms and coliform bacilli present are destroyed if the milk has been efficiently forewarmed. Thermophilic and thermoduric organisms grow rapidly at high temperatures, and certain precautions as to the quality of the milk and the care and cleanliness of utensils and plant are necessary if the growth of these organisms is to be avoided. In view of the processing to which the milk is subjected, it is obvious that condensed milk should possess a reasonably low bacterial content after treatment, provided raw milk of good quality has been used and that care has been taken during the processing.

(2) **Chemical Changes.**—As such changes affect the food value of the product, they are of no little importance. The changes which occur may be summarised as follows:

(*a*) A pellicle or skin commences to form upon the surface of the heated milk in contact with the air, at temperatures between 140° F. and 158° F. This pellicle has been found to contain a proportion of all the constituents in milk, but principally lacto-albumin. This formation does not occur when milk is heated in a closed vessel.

(*b*) Carbon dioxide is driven off and the constituent calcium and magnesium salts are precipitated while the bicarbonates are partially decomposed. The precipitation of the calcium salts renders the casein in milk less easily coagulable, this being the reason why heated milk will not easily coagulate. The addition of lime to heated milk will hasten the process of coagulation.

(*c*) Lecithin and nuclein are said to be decomposed.

(*d*) A decrease in the diffusible calcium and phosphorus content occurs when the milk is efficiently pasteurised.

(*e*) The vitamins indicated on page 229 may be affected by temperature or oxidation. Vitamin A, while stable to heat, is quickly affected by oxidation. Vitamin C is affected both by heat and oxidation and is the first of the vitamins to be destroyed during the heating process. The remaining vitamins are stable both to heat and oxidation.

(*f*) The enzymes will be destroyed by prolonged heating during forewarming. These enzymes are responsible for deterioration in the condensed milk during storage, and their destruction is essential in order that the product may possess satisfactory keeping qualities.

(*g*) Milk which has been treated by heat forms a finer curd in the stomach than does raw milk although it loses its viscosity.

(*h*) Phosphates present are precipitated by prolonged heating at high temperatures.

Manufacturing Process

The manufacture of raw milk into the condensed product is a lengthy and complicated operation which requires to be scientifically controlled at all stages of processing. It may be divided into the following separate stages:

(1) Preparation of the Milk.
(2) Forewarming.
(3) Addition of Sugar.
(4) Condensing.
(5) Cooling.
(6) Packing.
(7) Sterilisation of Plant.

The delicate nature of the milk and the easy manner in which imperfections develop therein have led to serious manufacturing difficulties. To overcome such difficulties, the plant has become extremely complicated,

and, in modern factories, elaborate systems of treatment before and after condensing are employed. The manufacture of sweetened condensed skimmed milk is similar in every respect to that of sweetened whole-milk.

(1) **Preparation of the Milk.**—The raw-milk supply must be of the highest quality, this being particularly important if the number of heat-resistant organisms is to be properly controlled. To ensure suitable supplies of raw
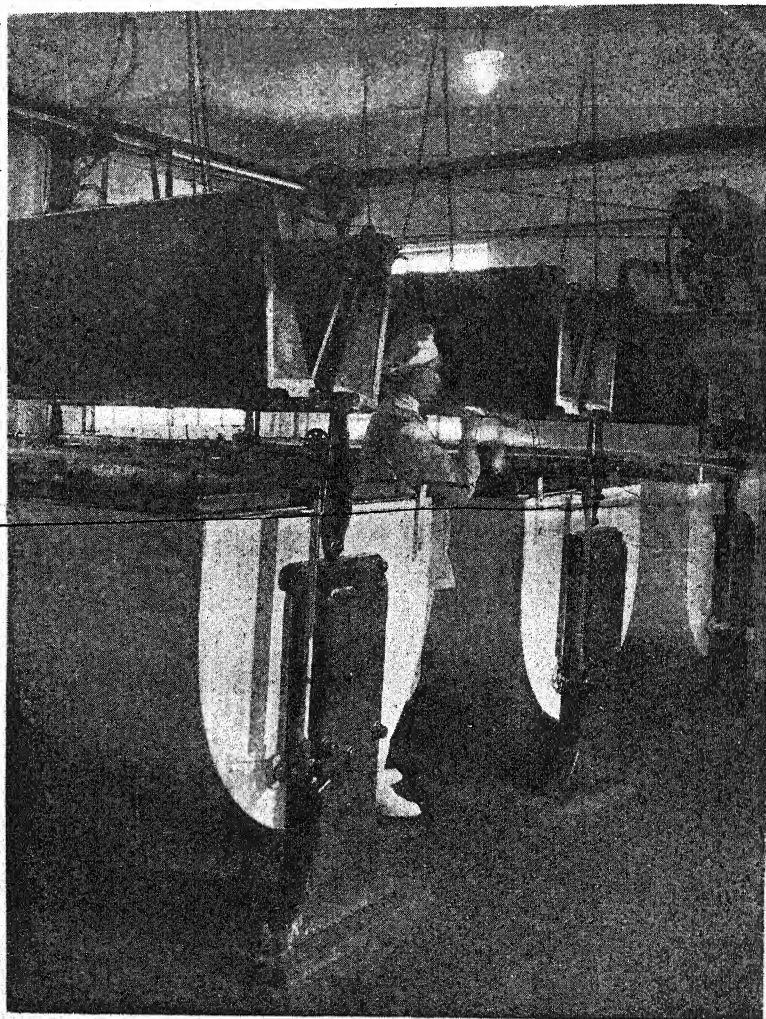
FIG. 59—Milk Standardising Tanks

milk, the methods of production at the farm require to be strictly supervised, and numerous routine tests are made at the factory to control the incoming supplies. Before the War, most reputable firms possessed a large staff of inspectors, whose duty it was to visit the farms from which the milk was obtained, at frequent intervals, the work of these inspectors being checked by the laboratory staff at the condensery. Great care must be taken to

ensure that milk possessing an appreciable acidity is not used, as condensed milk prepared from acid raw milk would possess a higher acidity than was originally present, owing to its reduced bulk. In addition, the incoming milk must be free from any abnormalities in composition due to disturbed mineral salt balance or associated with protein balance, while bacterial abnormalities must also be absent. In the past, it has often been assumed that inferior milk could be used for condensing purposes, but unless an absolutely clean sweet milk is employed for this purpose, difficulties are likely to ensue with production and in the final product.

When the incoming milk arrives at the receiving platform, it is examined for flavour, and samples are taken to determine the percentage of fat, solids-not-fat, acidity, and sediment. In addition, samples are submitted to methylene-blue reductase and resazurin tests, while fermentation tests are made and the *Bacillus coli* and bacterial content estimated. A description of the routine of these examinations will be found on pages 251 to 253. After these tests have been made, the milk is emptied through a wire screen into weighing pans, filtered or clarified to remove slime, cooled to 60° F. to retard bacterial growth, and run into large storage tanks, usually situated on the top floor of the factory. When in the tanks, the milk is standardised for fat and solids-not-fat. It is usual to examine samples of incoming milk by the Gerber method (see page 254) in order to obtain an estimation of its composition. This operation is of considerable import-ance, as the yield and keeping qualities are influenced thereby. Standardising consists of adding a sufficient quantity of cream or of separated milk to ensure that the resultant product contains the standard quantities of fat and solids-not-fat. Stanworth has suggested the following formula for deter-mining the weight of cream required for standardisation.

$$w = \frac{W(S - 2 \cdot 42F)}{f\left(2 \cdot 42 + \dfrac{S}{100}\right) - s}$$

where $w =$ Weight of cream.
  $W =$ Weight of bulk milk.
  $F =$ Percentage of fat in milk.
  $S =$ Solids-not-fat in milk.
  $f =$ Percentage of fat in cream.
  $s =$ Solids-not-fat in cream.   This may be obtained by the following formula:

$$s = \frac{S(100 - f)}{100}$$

The standardised milk is afterwards pumped into milk-supply tanks and is then ready for further treatment.

(2) **Forewarming.**—The milk passes from the milk-supply tanks to undergo the process of forewarming. The object of this process is to reduce the bacterial and mould content of the milk and to destroy the enzymes contained therein, which encourage slow chemical deterioration of the finished product. This treatment exerts an important influence upon the quality of the finished article, while, apart from the objects already indicated, some form of preheating is necessary in order to accelerate the process of

dissolving the sugar, which is added during the next stage of manufacture. The sugar dissolves much more readily in hot milk than in cold milk. Furthermore, it is not advisable to feed cold milk into the vacuum pans, for the following reasons:

(*a*) The cold milk would settle to the bottom of the pans and become burnt.
(*b*) Evaporation takes place more quickly if the milk has been preheated.
(*c*) The holding capacity of the pans would be reduced, and an increased period of exposure to the heating coils would be essential if the milk were cold.

The forewarming temperature varies from 145° F. upwards. In the United States of America, a temperature of 200° F. is favoured, but modern practice in this country favours temperatures between 190° and 205° F. to be used, as an aid to reducing the degree of thickening of the finished product during storage. If the reduction of the bacterial content and the acceleration of the sugar-dissolving process were the only objects in view, a high forewarming temperature would be most efficient, and it is for these reasons that many condenseries use such temperatures. The temperatures used have a marked effect upon the thickening of the finished product, however, and, from experiments carried out by various investigators, it would appear that the usual pasteurisation temperatures of 145° F. for thirty minutes or 162° F. for fifteen seconds are preferable to the higher temperatures sometimes employed. In many instances, part of the sucrose present in condensed milk is inverted by the action of moulds present in the raw milk. All moulds and their spores are destroyed at the temperatures mentioned.

The methods used to preheat the milk vary according to the ideas of the individual producers. In some cases, the milk is treated by the direct application of live steam. This is the oldest method of preheating and although it is open to many objections it is still employed in some factories in this country. The only advantage of this method is its simplicity, and when one considers the care taken to keep the product free from contamination throughout the remaining stages of the manufacturing process, it is surprising to find that this method is still tolerated. Blowing live steam into the milk will definitely encourage contamination, while a considerable quantity of condensed water will be added, which water must subsequently be evaporated. Apart from contamination, this is an uneconomic method, while, in addition, it is held responsible for an objectionable, stale flavour in the finished product.

In many condenseries, the milk is heated by contact with steam- or water-heated surfaces. The apparatus used varies considerably. Steam-jacketed pans, fitted with agitators to prevent the milk becoming burned, are sometimes employed. Some pans possess steam-heated revolving coils, while other factories use heaters of the continuous pasteurising type. Generally, when such heaters are used, a final heating to a high temperature is carried out by means of direct steam injection or by operating the heater under pressure. The internal surfaces of such pans should be constructed of stainless steel or glass enamel.

As a means of preheating the milk prior to condensing, a plate heat-exchanger, as illustrated in Fig. 8, page 33, may be used. This apparatus is now enjoying an increasing vogue as a means of forewarming the milk. The machine is constructed of heavily-tinned cast gunmetal or stainless-steel plates, grooved or provided with "knobs" on both sides. Similar plates are superimposed over these and are firmly secured converting the grooves

into shallow channels, the whole being tightly bolted together. Fig. 9, page 34, shows this type of plate. The milk to be treated flows across one side of the plates, the heating water flowing across the other side in the opposite direction. By this means, the liquids exchange heat, and, owing to the long shallow nature of the grooves, such interchange is extremely rapid.
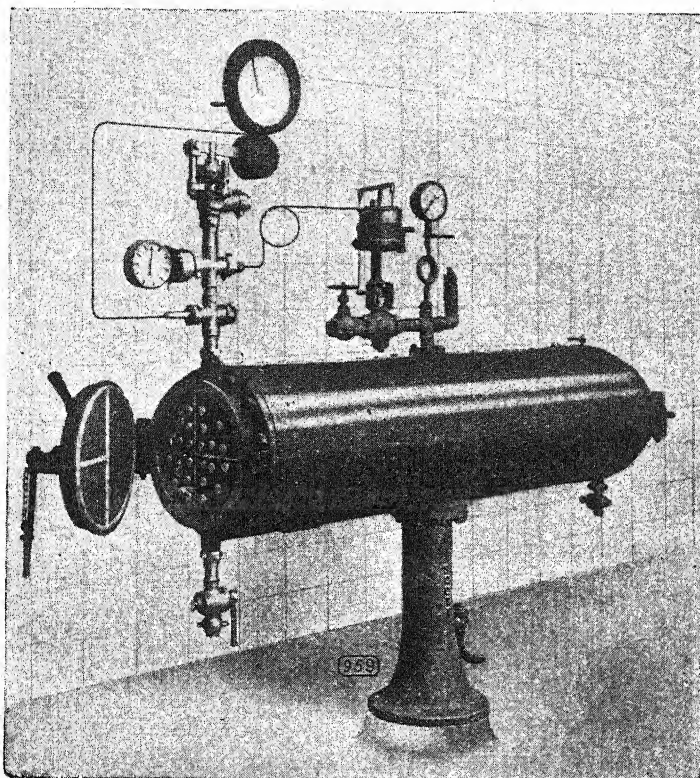
By courtesy of G. Scott & Son, Ltd.

FIG. 60—Multi-pass Preheater

The plates are assembled in a frame, and the capacity of the plant can be readily adjusted. The advantages claimed for the plate heat-exchanger are:

(a) The milk is not brought into contact with any direct steam or with a steam-heated surface, since the heating is carried out by water only a few degrees higher in temperature than the milk itself.

(b) The milk is never in contact with the air, thus avoiding contamination and oxidation.

(c) There is a complete absence of foaming.

(d) The machine is easily examined, cleansed with an ordinary brush, and sterilised by steam.

(e) An economy in the steam normally required for use is secured.

(f) A great saving in floor space is effected.

This apparatus can be arranged in such a way that the milk is preheated to any required temperature.

Multi-pass, tubular heaters, of the type shown in Figs. 60 and 61, constructed of stainless steel are generally employed for forewarming purposes.

In many Continental factories, the milk is heated or superheated to temperatures above 212° F. in a special type of closed heater. The milk is enclosed in a steam-jacketed vessel provided with a suitable agitator. The pressure attained in the closed vessel frequently rises to 15 lb. per square inch, which necessitates the apparatus being constructed in a robust fashion.
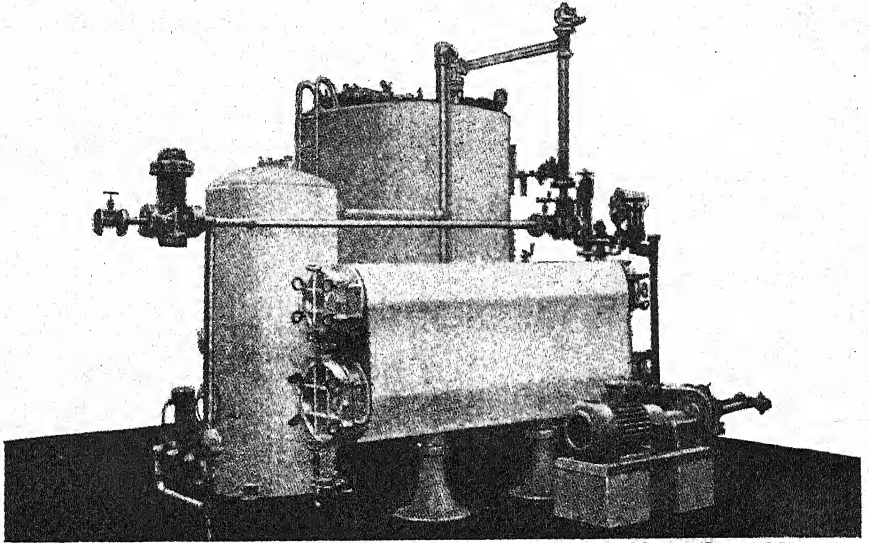
FIG. 61—Preheater and Heat-exchanger Unit for Condensed Milk Plant

(3) **Addition of Sugar.**—The next stage in the manufacture of sweetened condensed milk is the addition of sugar. The keeping quality of such milk depends both upon the preservative action of the added cane sugar and the concentration of the milk solids. Care should be taken to ensure that the sugar used is pure and not liable to ferment. The quantity added varies from 16 to 18 lb. for each 100 lb. of raw milk. The method of adding the sugar also varies. In some cases the milk is run from the preheater or pasteuriser to a sugar-mixing pan, where this material is mixed in a fine stream, mechanical agitation being used to assist dissolution. The use of what are termed *sugar wells* is a more satisfactory method. These wells are heated, small quantities of hot milk being run into them, and the sugar dissolved. The sweetened milk, together with the unsweetened milk, is then run into a mixing tank, from which it is drawn into the vacuum condensing pans. In this way the sugar dissolves easily without any disturbance of the state of solution of the milk constituents, while the rate of evaporation is also increased.

Another method is to dissolve the sugar by boiling it in water in a separate well. This mixture is then added to the milk. This method possesses the disadvantage that the additional water must subsequently be evaporated from the milk, although against this disadvantage must be placed the fact that the boiling of the solution destroys practically all the micro-organisms which the sugar may contain and obviates any possibility of undissolved sugar escaping into the vacuum pan, while the sugar solution can be filtered

to remove any extraneous matter such as paper or pieces of sacking which are quite often encountered.
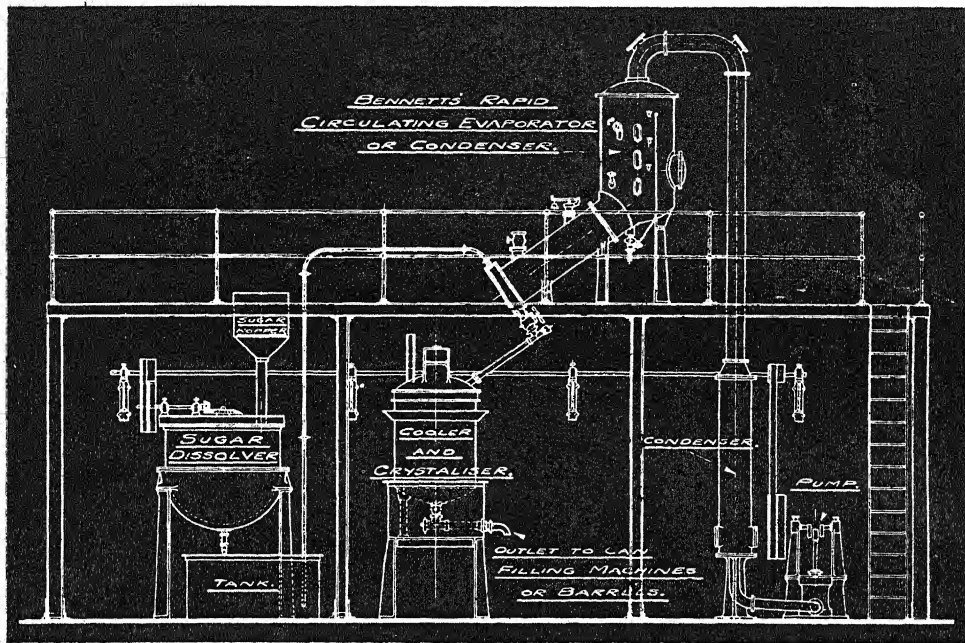
By courtesy of Bennett, Sons and Shears, Ltd.

FIG. 62—Plant for the Manufacture of Sweetened Condensed Milk

(4) **Condensing.**—Sweetened milk is concentrated to a greater degree than is the case with the unsweetened variety, being usually condensed to 75 per cent. total solids. Several methods are employed for condensing, as follows:

(a) The Atmospheric Method.
(b) The Vacuum-pan Method.
(c) The Dry-air Method.

(a) *The Atmospheric Method.*—This method is used by many small producers of condensed milk. The milk is drawn from the mixing tanks into pans, which are fitted with revolving submerged discs internally heated by steam. The evaporated steam is carried off by fans. The heat applied with this method must be considerable if the moisture is to be quickly removed, while the food value of the product is likely to be affected. This method has now been almost entirely superseded by the vacuum-pan method.

(b) *The Vacuum-pan Method.*—This method is employed in the majority of large condenseries, the milk being condensed in various forms of stainless-steel, tubular calandria pans which are provided with either internal or external heating systems and work under reduced pressure. The pans are fitted with steam coils internally, and the lower portion is steam-jacketed. The steam pressure is usually 20 lb. per square inch. The operation is carried out at temperatures between 125° and 130° F., the milk boiling at this

temperature owing to the reduced pressure—20 inches of vacuum—which is maintained in the pans. In this way the milk proteins are not coagulated, while the lactose is not burnt.

The pans are sterilised by steam before operations commence, and the vacuum pumps are operated until a 20-inches vacuum is obtained. The inlet valves are opened slightly and the milk is drawn into the pans by the action of the reduced pressure. As each section of the heating coils is covered, steam is gradually admitted, but care must be taken not to admit any steam to the uncovered coils. When the heated milk enters the pan, it begins to boil, and large quantities of air are expelled, this causing foaming (the question of the prevention of foaming is dealt with later, on page 242). When the milk-level is sufficiently high to cover the heating surfaces, the inlet is partially closed in order to maintain the milk at a constant level. The heated milk is drawn into the pan continuously, the rate of entry being fixed in such a way that, when the last of the milk has entered the pan, only a further fifteen minutes' processing is necessary to produce the required concentration. During this process, the heat is so applied as to ensure that the milk will boil vigorously, a working vacuum of between 24 and 25 inches being attained, but, towards the end of the concentration process, the heat is reduced, to prevent the thickened milk from burning. In addition, if any of the coils become exposed the steam passing to those coils is turned off. In some instances the condensed milk is superheated by means of dry live steam before the pan is emptied. A spray of water is used to condense the vapour from the pans. The temperature of the condensed water is usually in the neighbourhood of 110° F. There is a direct relationship between the outlet temperature of the condensing water and the boiling point of the milk, and very careful control is necessary
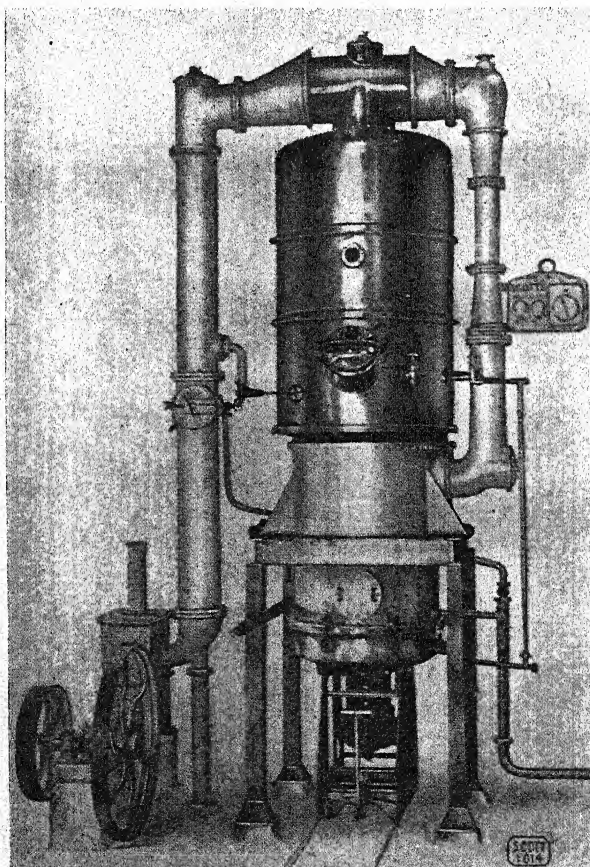
By courtesy of G. Scott & Son, Ltd.

FIG. 63—Milk-condensing Plant with Thermo-compressor

as regards this water temperature, otherwise control of the pan is likely to be affected.

The speed with which the milk is condensed to the desired consistency depends upon the following factors:

(i) The quantity of milk in the pan.
(ii) The area of the heating surfaces.
(iii) The capacity of the vacuum pump.
(iv) The temperature of the condenser.

The exact time which the processing should occupy is not a simple matter. The process of condensing usually requires some three hours, but the precise point at which the batch should be "struck" depends largely upon experience. Samples are taken at regular intervals by means of the sampling cocks with which the pans are provided, a Beaumé hydrometer or a viscometer being used to determine the progress of concentration. When the reading shows 32° and the temperature of the milk is 120° F., the batch of milk is ready for removal from the pans. The steam is shut off, the vacuum broken, and the milk run off to cool.
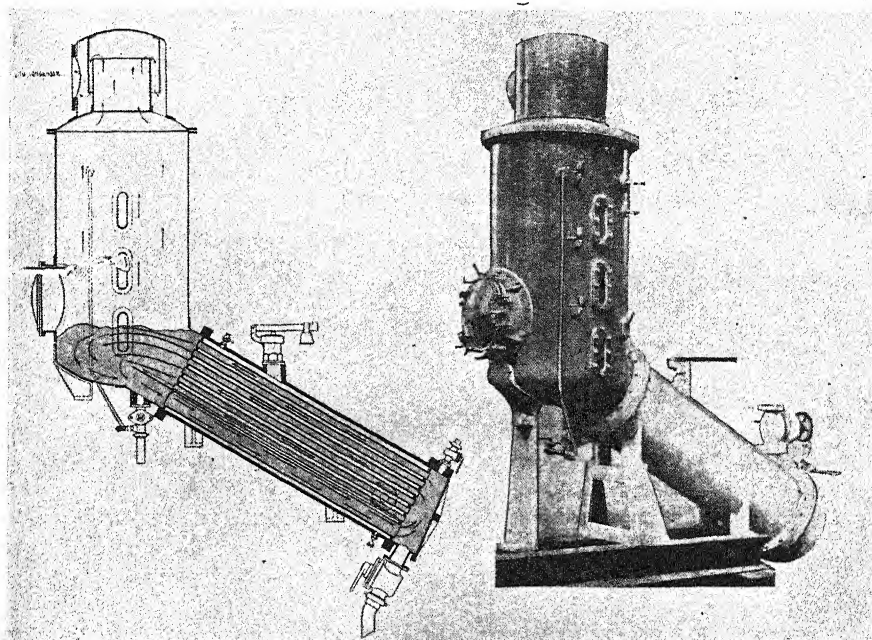
By courtesy of Bennett, Sons and Shears, Ltd

FIG. 64—Patent Rapid Circulating Evaporator

(c) *The Dry-air Method.*—This method employs dry air to remove the water from the milk. The milk is heated to 140° F., at which temperature it remains for some two hours. During this period, warm, dry air is pumped through, producing considerable agitation and effecting evaporation of the water. This method has never been popular in this country.

As the vacuum-pan method is the most popular means of condensing milk, the operation of such pans requires some further and more definite consideration. It is possible to condense milk by boiling and, in such a case,
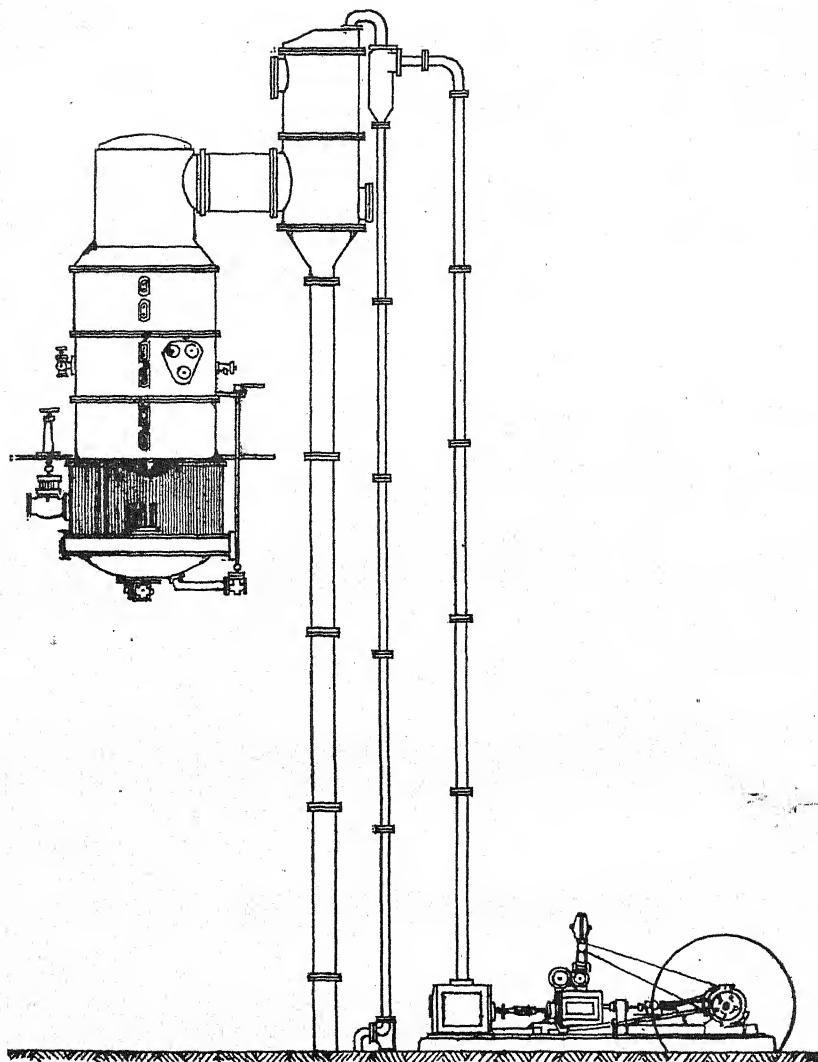
FIG. 65—Vacuum Pan and High-level Condenser

only a simple boiling pan and heating coil would be required. To give the milk satisfactory treatment, and to preserve its colloidal equilibrium, it should not be heated to a temperature in excess of 140° F. for any length of time. It is, however, possible to concentrate milk in a pan open to the atmosphere at this temperature, but the evaporation of the water content would be slow and the cost prohibitive if large quantities had to be treated. It is usual, therefore, to employ other methods, of which vacuum pans are the principal exponent. There are two types of pans:

(i) The *coil type*, in which the heating agent passes through coils immersed in the milk (Fig. 65).
(ii) The *calandria type*, in which the milk is heated by circulating through vertical tubes which stretch between horizontal tube plates. The steam used for heating acts upon the exterior of the milk tubes (Fig. 64).

In both these types, the lower part of the pan may be steam-jacketed. There are also film evaporators, which will be mentioned later.

The vacuum pan is an airtight vessel and may be constructed of a variety of metals. *Copper* was formerly used, but this metal and most of its alloys exert a catalytic action upon the milk, followed by oxidation, with the consequent appearance of a tallowy flavour in the product. *Iron* is useless, while *zinc* and *aluminium*, although soluble in lactic acid, do not flavour the product. *Aluminium* is excellent, provided always that it is carefully cleaned, but has achieved little popularity. Neither has *tinned copper*, which is only a satisfactory material if the coating of tin is of requisite thickness and quality. *Stainless steel* and *glass enamel* are ideal for the purpose and are enjoying increasing popularity, the former metal being almost universally employed.

Low-pressure steam is used for heating vacuum pans with considerable saving in fuel costs, which would not be the case if milk were evaporated at atmospheric pressure. The milk occupies the lower half of the pan, the vapour being led off from the upper half of the dome-shaped top, to a condenser. If steam is cooled in a closed vessel, a vacuum is set up. The condenser employed operates on this principle. Steam is admitted continuously to maintain the vacuum and is immediately cooled sufficiently to condense it to water. A pump is fitted to exhaust the air entering with the steam at a sufficient speed to maintain a constant vacuum. This is essential, as steam contains a certain amount of air which is not condensable. The primary use of vacuum pans is to evaporate the milk at temperatures which do not affect its properties in an adverse manner.

Steam is required for operating the condenser, cooling water, and extraction pumps, and the size of such pumps varies according to the type of condenser. There are two types of condenser in use:

   (i) The *surface condenser* requires a small air pump, but more power for cooling-water circulation, as the steam is condensed by coming into contact with copper tubes through which the cooling water is flowing.

   (ii) The *jet condenser*, in which condensation takes place by the application of jets or sprays of cooling water to the steam. In this type, large air pumps are necessary, but less power for water circulation is required.

Jet condensers are of two types:

   (i) *Low-level condensers*, in which the condensate and cooling water are extracted by a pump.

   (ii) *High-level condensers* placed 34 feet above ground-level and fitted with a pipe, the lower end of which is immersed in a well.

Fig. 65 illustrates the arrangement of a vacuum pan and high-level condenser. For condensing the vapour from the pans, a copious supply of cold water is essential and should be situated adjoining the factory. If this is not the case, spray ponds and cooling towers will be necessary, as each condenser must be capable of dissipating as much heat as is given up by the steam used to heat the coils in the vacuum pans. Some vacuum pans are constructed with the condenser fitted inside the pan, near the dome. It is claimed for this type that no power is required to draw the vapours from the pan to the condenser.

Rapidity of evaporation is essential, and this demands the maximum rate of heat transference. In turn, this can only be obtained by a rapid circulation of the milk. In the coil-type pan, the milk circulation depends upon the tendency of the hotter milk to rise, and thus set up circulating currents. In calandria-type pans, however, separate up-take and down-

comer tubes are provided, but a serious difficulty is apparent. As the viscosity of the milk increases, the circulation decreases, whereas, in the coil type of pan, the circulation is not so definite. Forced-circulation evaporators, as illustrated in Figs. 64 and 66, have been designed to force the milk through the heating tubes, and so overcome the difficulty. The milk is delivered from the heater to the vacuum pan, cooled by evaporation, and is recirculated through the heating element.
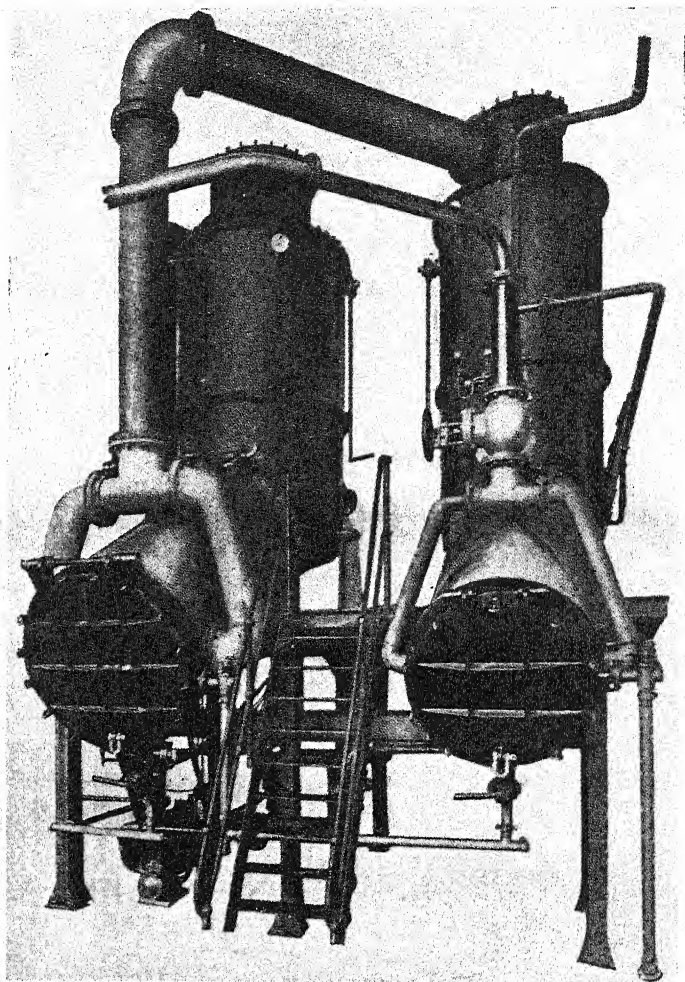
By courtesy of Bennett, Sons and Shears, Ltd.

FIG. 66—Patent Double-effect Evaporator

Foaming sometimes occurs, due to the release of the air contained in the milk. This may cause difficulty at certain stages of the process. When sugar is added to fresh, warm milk, a portion of the air which the milk contains is driven out and foaming occurs in the sugaring wells. In addition, when milk is heated under vacuum, the air is rapidly driven out of solution, foam forms quickly and, if care is not exercised, the milk may be carried over into the condenser. It is usual to check foam formation by opening

the air-break valve fitted to each pan. The formation of foam may also be diminished by providing ample heating surfaces and using the lowest possible steam temperature. Evaporators with external heating elements and the Kestner film evaporator minimise the risk of foaming.

Two of the most important manufacturing factors governing the quality of the finished article are:

(i) *The Temperature of the Milk and of the Steam used for Heating.*—These must be maintained at as low a level as is consistent with satisfactory working.

(ii) *The Period of Time during which the Milk is exposed to the Heating Surface.* —This should be as short as possible, and is best obtained by evaporating at high speed.

The steam used for heating is generally engine exhaust steam from which the oil has been separated. This is occasionally mixed with steam direct from the boiler; the steam is admitted to the low-pressure pipes through reducing valves. The higher the vacuum maintained in the pans, the quicker the evaporation process will be completed, while, in addition, the pans can then work at greater capacity. Practically, however, too low a temperature or too high a vacuum cannot be employed. To operate successfully, condenseries require cheap power and plentiful supplies of cold water, as the factory can make use of a higher vacuum than is possible if the cooling water has to be carefully conserved. In addition, the higher the vacuum used, the greater must be the size and power of the air pumps. In practice, a 26 inches vacuum is the highest employed. This is generally maintained at 25 inches until excessive foaming has ceased.

The question as to whether condensing should be carried out in batch pans or continuously requires careful consideration. There can be little doubt that continuous condensing is much more economical and satisfactory if large quantities of milk are to be dealt with. The capacity of the plant is increased, with a consequent economy in time, labour, and fuel, while a more uniform product is obtained. When the pans are operated continuously, the milk is either drawn off by a pump or is discharged into collecting pans under vacuum. An automatic density tester is usually fitted to the milk outlet, in order to ensure the continuous maintenance of a suitable density. In pans operated on the continuous system, the inlet for the milk is level with the surface of the milk in the vessels, the outlet being fixed at the base. To ensure satisfactory working on continuous lines, the correct proportioning of the sugar and milk mixture is important, and it is probable, in practice, that the only really satisfactory way is to make up batches of milk and sugar in predetermined proportions and ensure that these are fed to the condenser from a properly agitated tank. Difficulty is also experienced in attaining a final product which possesses an absolute final standard density.

(5) **Cooling.**—When the milk attains the proper degree of concentration, it is drawn off and cooled. This operation is essential if thickening is to be prevented, and if the texture of the product is to be controlled. The quantity of sugar which milk can carry in solution varies according to the temperature of the milk. Sweetened condensed milk is a highly saturated solution of lactose and, as it cools, the sugar crystallises out. It is essential that these crystals should be as minute as possible and should not be gritty. For this reason, this type of milk should be cooled rapidly in the initial stages, and then more slowly. Crystallisation is usually assisted by the

addition of a small quantity of condensed milk taken from a previous batch, or by the addition of some powdered lactose. The milk is finally cooled to a temperature of approximately 63° F.

The methods used for cooling vary, as follows:

  (i) The milk may be run into 10-gallon tapered pans, which are immersed in large tanks of running water. The milk is agitated during the cooling process by means of stirring rods fitted with paddles, which are coupled to an overhead revolving shaft. In some cases, the pans are revolved, while the agitators remain stationary. This method is now very rarely used.
  (ii) The milk may be pumped through coils submerged in running water.
  (iii) The milk may be run into vats provided with coils through which cold water is passed. The coils are made to revolve, in order to ensure that the necessary agitation is provided.
  (iv) Use may be made of a combined vacuum pan and encrystalliser, in which the cooling is effected in the pan itself.

(6) Packing.—It is essential that the milk should be packed or canned immediately after it has been sufficiently cooled. Two types of packages are used. For bulk transport, the milk is filled into *barrels* of various sizes, which hold from 300 lb. to 700 lb. each. The barrels are coated internally with wax to minimise any risk of contamination by mould spores. Before the milk is run into the barrels, they should be sterilised by means of steam, allowed to drain, and then filled by means of a funnel placed in the bunghole. When the barrels are full, the bungs are driven in, thus effectively sealing the contents.

When sold retail, the milk is packed into *cans* containing from 8 ozs. to 1 gallon of the sweetened milk. The process of canning has been developed to an extraordinary degree within recent years. The methods used vary from hand filling to the use of complicated machinery. Machines for filling the cans may be obtained in a variety of types, while, in some condenseries, tinned sheets are automatically converted by machines into cans, which are immediately filled and sealed automatically. In small factories, the cans are bought ready for use and are filled and sealed by hand. Sealing is carried out either by means of solder or by crimping on the tops of the cans to form an airtight seal without the use of solder.

The cans should be sealed immediately after they have been filled, in order to prevent the entrance of dust or flies, and to prevent any deterioration of the product by exposure to light and air. Some cans are open, the top being sealed on after filling, while others have a small aperture, the opening being hermetically sealed after filling has been completed. The cans are supplied to the filling machines by special chutes, as the can room does not normally connect direct with the room in which the cans are filled.

In order to assist in the preservation of the contents, the cans are sometimes exhausted before sealing takes place. Either of two methods may be employed for this purpose:

  (i) The Vacuum Method.
  (ii) The Atmospheric Method.

(i) *The Vacuum Method.*—Cans which are to be exhausted by this method are filled and the lids and caps soldered on while a small aperture in the centre is covered with a loose piece of solder. They are fed into a vacuum-sealing machine which possesses a chamber connected to a powerful vacuum pump. When the chamber is filled, the openings are loosed and the pump is operated until a vacuum of 25 inches is registered on the gauge

provided. The small central aperture is sealed by means of an ingenious device while the cans are still in the vacuum chamber. A 25 inches vacuum is obtained inside the closed tins, the ends being concave.

(ii) *The Atmospheric Method.*—The capped cans provided with an unsealed aperture pass by means of a travelling belt or worm drive to an automatic filling machine. The cans then pass to a sealing machine, which seals the apertures in the lids.

When the sealing process has been completed, the cans are labelled in accordance with the statutory requirements indicated on page 259.

(7) Sterilisation of Plant.—As with all plant or utensils used in the preparation of foodstuffs, the apparatus and containers used in the production and packing of condensed milk require a thorough cleansing and sterilisation after use. All internal surfaces of the plant should be washed, first with cold and then with hot water, and finally sterilised by means of live steam. The caked milk should always be carefully removed, while the connecting pipes should consist of short, straight sections, which may be unscrewed, brushed through, washed, and steamed.

Inspection of Cans

As both types of condensed milk are retailed in cans, the method of inspection of such cans requires brief mention. The examination usually consists of a physical inspection of the unopened cans, which should be carried out in two stages, as follows:

(1) Superficial Inspection.
(2) More Detailed Physical Inspection.

(1) Superficial Inspection.—Such an inspection will reveal indentations, signs of rust, apertures, or leaking cans. Stains on the exteriors of the cases should in every case be followed by a further investigation of the contents. Rusted cans do not necessarily mean that the contents are unsound, as such cans may be old stocks or may have been subjected to ill-usage. If, however, the cans in a consignment are badly rusted, they should be carefully inspected, as a number of cans may be rusted through.

(2) More Detailed Physical Inspection.—The cans should be palpated to detect if any are "blown," "swelled," or "springy," these being the principal causes of condemnation. The ends of such cans are distended or bulging, due to gaseous decomposition. The presence of gas may be detected by rapping the cans with the knuckles. Such cans will emit a drum-like note. Yeasts which are capable of resisting high temperatures or prolonged heating often produce decomposition in cans of sweetened condensed milk. Those cans will be badly "blown," owing to the presence of carbon dioxide formed by the alcoholic fermentation of the sugar. The contents of such cans are rancid and highly odorous.

The presence of a second sealed vent-hole should be viewed with suspicion, as this may indicate the fact that the can has been punctured to allow gas to escape and subsequently resoldered.

Bacteria in Condensed Milk

Sweetened condensed milk is not sterilised either before or after it is canned, reliance being placed upon the low moisture content and the preservative action of the sugar to inhibit bacterial growth. In spite of this,

although even sound cans of milk are never sterile, they remain sound and wholesome for months, and in some cases for years. In order to appreciate the reason for this comparative immunity from deterioration and also the converse fact that the contents of the cans are sometimes decomposed, the bacteria which may be present in the condensed product require consideration. Apart from those which may remain undestroyed by the fore-warming and evaporation processes, others obtain entrance from the air during cooling, and from the cans into which the milk is filled, as these are never sterilised before filling.

The following *non-pathogenic* organisms have been found in sweetened condensed milk by various investigators:

(1) *Sarcinæ*.
(2) *Staphylococci*.—These may be present in large numbers without any apparent ill-effect to the consumer. *Staphylococcus aureus* grows with great rapidity in condensed milk.
(3) Organisms of the *proteus* group.
(4) Spore bearers of the *Bacillus subtilis* group.
(5) *Streptococcus fætalis* and *Streptococcus albus*.
(6) *Bacillus coli* and other coliform organisms. These organisms apparently possess little power of growth in the milk.
(7) *Bacillus mesentericus*.
(8) *Bacillus thermoin differens*.
(9) Thermophilic and thermoduric organisms. These have no public health significance.
(10) Diplococci.

Micrococci are found in all types of condensed milk. Many of these organisms are highly resistant to heat and survive the processing, while others are added during subsequent treatment. They are capable of rapid increase in the finished product. Anaerobes are found, but are not an important cause of decomposition, as the concentrated, viscid milk is an unsuitable medium for their development. The same remarks apply to coliform organisms. The latter are not responsible for the formation of gas in the cans. Spore-bearing aerobic bacilli are invariably found, both in sound and unsound cans of sweetened milk. As they are actively proteolytic, they probably initiate decomposition in the milk, in conjunction with diplococci. The heat-resisting group of organisms are generally present, but are not responsible for decomposition of the milk.

Yeasts are exceedingly plentiful and are present either in the milk, when they will survive the heating processes, or may be derived from the sugar, from the air, or from the utensils and plant. Two types of yeasts are commonly found, of which the fermenting variety is the most serious, being responsible for gas production and "blown" cans. Because of the nature of the milk and the restricted oxygen supply, yeasts grow with some difficulty, but, if they can secrete sufficient ferment to break down the saccharose before the oxygen supply is exhausted, their enzymes can produce gas. The fermenting yeasts are harmless to human beings, but render the contents of the cans unsaleable. It is therefore essential that the milk should be heated sufficiently to destroy the yeasts present in the raw milk, while it is usual to keep each batch of cans in a warm room for several weeks to ascertain whether or not any defects develop.

In short, although non-pathogenic micro-organisms are initially present in all cans of sweetened condensed milk, the viscosity and high sucrose content, together with the absence of oxygen, render existing conditions

unsuitable for their growth. Most of the bacteria present are the result of multiplication following the condensing process. It should also be remembered that those organisms which may be present in the cans will multiply rapidly when they are opened, and it is therefore essential that the milk should be consumed as quickly as possible if harmful results to the consumers are to be avoided.

Pathogenic bacteria should not be present in condensed milk if the product has been properly preheated or pasteurised before evaporation. *Mycobacterium tuberculosis* is the most important pathogenic organism found in raw milk. Delepine has shown that tubercle bacilli have resisted the process of pasteurisation commonly adopted in condensed milk manufacture. He also showed that these bacilli were still capable of producing tuberculosis in guinea pigs inoculated with the milk, but that the course of the disease was very much slower than that of the disease produced in guinea pigs inoculated with untreated tuberculous milk. Generally speaking, it may be stated that tuberculosis produced by heated bacilli is latent for some four weeks. Pathogenic organisms of human origin may be added to the milk from human sources after it leaves the vacuum pan, but such organisms rapidly succumb.

Defects in Condensed Milk

The defects which may occur in condensed milk of the sweetened variety may be divided into two classes, as follows:

   (1) Bacterial Defects.
   (2) Non-bacterial Defects.

   (1) **Bacterial Defects.**—These defects are due to the presence of abnormal bacteria in the milk. The commonest defects found are :

   (*a*) Gassy Fermentation.
   (*b*) Bacterial Thickening.
   (*c*) Buttons.

   (*a*) *Gassy Fermentation.*—This defect is of frequent occurrence and is the cause of considerable loss to manufacturers. The evolution of gas takes place in the cans or barrels of condensed milk, the gas formation being sufficient in some instances to bulge or even burst the containers. The milk from such containers will be found on examination to possess a high percentage of acidity, while it will be lumpy and unfit for sale. The internal metal surfaces of affected cans are usually discoloured and darkened, instead of exhibiting a normal, bright appearance.

Organisms of the *Bacillus lactis aerogenes* type are particularly liable to produce gas in considerable quantities. Although such organisms should be destroyed if the forewarming temperature is sufficiently high, they may obtain entrance to the milk subsequently by means of fly pollution. These organisms will not grow in milk containing more than 40 per cent. of sucrose, but in milk in which the sugar has crystallised out to an appreciable extent they may develop with great rapidity.

Gas-producing yeasts are the cause of many gassy fermentations. *Torula lactis condensi* will grow in media containing fermentable sugar and produce considerable quantities of gas. *Torula saccharalis*, *Torula globosa*, and similar types will also ferment condensed milk, with the evolution of gas.

Yeasts present in unsound cans may vary from thousands to millions, variations in the results of enumeration being accounted for by their uneven distribution.

Savage and Hunwicke, in 1923, investigated the causes of gas production in tins of condensed milk, and reported that yeasts were the cause of this defect in every case. They isolated eight different types of yeasts, as follows:

Type A.—Spherical yeast which fermented dextrose, sucrose, and maltose, but not lactose.

Type A_1.—Similar to A, but did not ferment maltose.

Type A_2.—Ellipsoidal, but otherwise similar to A and A_1.

Type B.—Very ellipsoidal, fermented maltose, but not dextrose, lactose, or sucrose. Also fermented dilute condensed milk.

Type C.—Ellipsoidal, but did not ferment dextrose, lactose, sucrose, or maltose.

Type D.—Almost spherical. Properties similar to C.

Type E.—Pink yeasts which possessed no fermentation properties.

Type F.—Large, ellipsoidal yeasts which fermented dextrose, but not lactose, sucrose, or maltose. Did not form gas in diluted condensed milk.

These investigators published the following table, showing the distribution of these types among the sources investigated:

TABLE 14

DISTRIBUTION OF YEASTS AMONGST VARIOUS SOURCES
(SAVAGE AND HUNWICKE).

Source	With Fermentation Properties					With No Fermentation Properties				Type not worked out
	Type					Type				
	A	A_1	A_2	B	F	C	D	E	G	
Rejected Blown Tins . .	16	8	1	5	3	1	4	1	—	—
Rejected, not Blown . .	—	1	—	1	—	1	2	—	—	—
Sound Shop Tins . .	—	—	—	—	—	2	2	—	—	—
Sound Fresh Factory Tins .	—	10	—	—	—	2	3	1	1	—
Incubated Fresh Tins. .	1	7	—	—	—	2	3	2	—	—
Fresh Milk Samples . .	—	2	1	—	—	2	3	2	—	—
Air Plates . . .	1	5	—	—	—	2	5	3	—	—
Sugar Samples . .	—	—	—	—	—	1	1	—	—	—
Deposit from Pipes . .	1	1	1	—	—	1	—	1	—	—
All sources . . .	19	34	3	6	3	14	23	10	1	4

Knudson in 1922 and Hiscox in 1923 isolated two identical yeasts from blown or burst cans of condensed milk. One of these yeasts was circular, while the other was oval, the latter being much more vigorous than the circular type. These yeasts were capable of fermenting milk containing 70 per cent. of sucrose, the milk coagulating with the production of large quantities of gas. The thermal death-point of the circular yeasts in saline was in the neighbourhood of 140° F., while that of the oval type was slightly lower, being 131° F. In sweetened condensed milk, the thermal death-point of the oval yeasts was not affected, but a temperature of 185° F. was required to destroy the circular type.

The sources of contamination are many and varied. The raw milk supply may contain these yeasts, but if the milk is efficiently preheated and pasteurised, this should not be a serious source of infection. The air of the factory is a possible source of contamination, while the apparatus, particularly the plant used for cooling and filling, may produce many yeasts. In certain cases, the sugar may also be a source of contamination. It is important to remember that only sugar of the highest quality should be used. This should be stored under clean, dry conditions. Inferior-quality sugar often contains large quantities of what is known as "invert sugar," which encourages the growth of bacteria and yeasts. If the sugar is allowed to become damp and sticky, it attracts flies and encourages the multiplication of certain types of organisms. Unsound factory methods may also be a source of contamination, as such practices are readily followed by the growth of yeasts on utensils and plant.

The principal factor influencing the growth of yeasts is the oxygen supply. Most yeasts require a preliminary aerobic growing stage before they will grow with rapidity under anaerobic conditions. The packing of the milk in airtight or air-exhausted cans, containing no oxygen, would thus be likely to inhibit the growth of yeasts.

(b) *Bacterial Thickening.*—Sweetened condensed milk frequently suffers from a progressive thickening, of which one type at least is due to the action of micro-organisms. This defect is most prevalent during summer or in tropical countries, being most liable to occur at high temperatures. Cocci appear most active in producing this defect, although the individual types responsible have not yet been completely identified. It is, however, thought that one type resembled *Streptococcus albus* and another, *Micrococcus freudenreichii*. These organisms are easily destroyed by the preheating process, but the milk may become infected during the remainder of the processing from the plant and utensils. As a preventive measure, it is usual to ensure a concentration of 64·5 per cent. sucrose, but, if the milk is stored at reasonably low temperatures, it will not thicken, even when a lower concentration is used. Some cocci do not ferment lactose or sucrose, but coagulate the milk. This is due to the formation of a rennin-like enzyme.

(c) *Buttons.*—The cause of "buttons," as they are known to the trade, is due to the mould *Aspergillus repens*. This defect occurs after storage for some time. Small reddish-brown pieces of curd, usually $\frac{1}{4}$ inch to $\frac{3}{4}$ inch in diameter, which possess a firm, cheesy consistency, are formed, and these render the milk unmarketable, although they do not affect the flavour. The causative mould produces what is known as a "clotting enzyme," which causes localised coagulation. The milk usually becomes infected from the concentration process, but if scrupulous cleanliness and care are exercised, the milk will not become contaminated. The organism does not grow at low temperatures. Such temperatures during storage will prevent this defect, while the exclusion of oxygen will also assist. *Aspergillus repens* will not grow in tins which have been exhausted with a vacuum of over 20 inches.

(2) **Non-bacterial Defects.**—The non-bacterial defects, i.e. those of a chemical or physical origin, are as follows:

- (a) Grittiness.
- (b) Thickening.

R

(c) Lumpiness.

(d) Rancidity.

(e) Brown Coloration.

(a) *Grittiness.*—Good-quality condensed milk should possess a smooth and homogeneous texture and be pleasant to the palate. Sometimes, however, the milk may be gritty, containing large numbers of small, hard crystals, whose presence is at once apparent to the consumer. This defect is due to the presence of lactose crystals, and arises through the use of faulty cooling methods after the milk has left the vacuum pan. Cooling must be carried out in such a manner that the smooth texture of the milk is preserved by the formation of large numbers of minute sugar crystals. If the crystals are few in number and large in size, the texture will be gritty.

The cooling of the milk, as described on page 243, is exceedingly important. When the condensed milk leaves the vacuum pan, it is a supersaturated solution of lactose. To ensure that large numbers of small crystals are formed, it is necessary to induce rapid crystallisation at that point during the cooling operations when the super-saturation is high, and the viscosity of the milk is at its lowest level. High viscosity delays the crystal formation. It is therefore necessary to cool the milk rapidly in the initial stage, after which powdered lactose or condensed milk from a previous batch is added, the mixture being vigorously agitated during the entire period. Further cooling to the final temperature of 63° F. is delayed for twenty-five minutes. The resultant product should be free from grittiness.

(b) *Thickening.*—In addition to the bacterial thickening due to the presence of abnormal organisms, another type of thickening exists which is apparently due to changes in the colloidal constitution of the albumin and casein. Various research workers have discovered that certain factors affect the thickening process. These are:

(i) *The Albumin and Casein Content.*—When the albumin and casein are heated above their coagulation points, the effect upon the progressive thickening is marked.

(ii) *The Mineral Salt Content.*—Rogers, Deysher, and Evans added citrate and phosphate to milk. It was then found that the addition of citrate did not cause thickening of the product. When the phosphates were added in quantities sufficient to increase the total by 7 to 10 per cent., the thickening tendency of the milk was influenced. The salts contained in the raw milk have been proved to be the main factor influencing the heat coagulation of the milk, the calcium and magnesium salts present balancing the effects of the citrate and the phosphate. The progressive thickening of condensed milk at normal temperatures appears to occur in a similar manner.

(iii) *The Preheating Temperature.*—With high preheating temperatures, there is a greater tendency upon the part of the product to thicken than if a lower temperature of 145° F. were used. For this reason, preheating at pasteurising temperature is recommended.

(iv) *The Concentration of the Milk.*—The degree to which the milk is concentrated affects the thickening tendency. With increasing concentration of the milk solids, the thickening tendency becomes more marked. The temperature of the vacuum-pan process also affects thickening. This should not be higher than 145° F. and the batch of milk should be finished at this low temperature, while the product, after treatment has been complete, should be immediately withdrawn from the pan and cooled.

(v) *The Storage Temperature.*—Storage at temperatures below 60° F. is essential to prevent this type of thickening.

(c) *Lumpiness.*—Lumps, which may be either soft or cheesy, are some-times found floating in the milk. This defect is not of bacterial origin, the two main causes being:

(i) *The Concentration of Raw Milk containing an unusually High Percentage of Albumin and Globulin.*—Such milk tends to form a gelatinous coating around the heating coils of the vacuum pan, which in time becomes detached to form lumps in the milk last drawn from the pan. To overcome this difficulty, the last portion of the milk is separated from the remainder of the batch, the lumps are dissolved in warm water, and this mixture is recondensed with a fresh batch. A strainer is sometimes fixed to the outlet of the vacuum pan, but this retards the discharging process and prolongs the period during which the milk remains in the pans.

(ii) *The use of an acid flux in sealing the cans* has also been proved to be a cause of this defect. The lumps thus formed are usually found attached to the seam of the can and generally exhibit a distinct reddish colour. The use of an acid flux which contains zinc chloride will exert a toxic effect. The formation of such lumps can usually be prevented by using an acid-free flux.

(d) *Rancidity.*—This defect is infrequent, but when the product does become rancid, it is rendered unfit for consumption. Several reasons exist for the occurrence of this defect. The raw milk drawn either at the beginning or end of a cow's lactation period possesses a high lipase content, this being thought to be one of the causes. A further cause is the contamination of the milk with bacteria, yeasts, or moulds, which secrete lipase. Badly polluted water supplies containing such organisms, particularly *Pseudomonas fluorescens*, is also a contributory cause, and it is therefore particularly important that the water supply shall be perfectly pure. Rancidity develops between one and two months after canning and is at once noticeable when the can is opened. As the defect develops, the contents become more viscous until they finally become solid.

Rancidity is likely to occur if raw or improperly-heated milk is accidentally drawn into the vacuum pan at the time of concentration. This may occur as a result of carelessness in methods of preheating the milk, such as the failure to destroy the lipase or the existence of leaking intake valves.

(e) *Brown Colour.*—Sweetened condensed milk usually becomes darker in colour during storage, but, upon occasion, this change is exaggerated until the product exhibits a dark-brown tint. Various authorities have stated that this defect is probably due to the slow formation of humus, caused by the interaction between sucrose, lactose, and milk proteins. The acidity and temperature are also factors which determine the rapidity of the change. This defect may be avoided if the cans are stored at reasonably low temperatures. The development of a dark-brown colour may be retarded indefinitely if the milk is kept in cold storage.

Bacteriological Control

(1) **Raw Supplies.**—The following tests, which have already received mention on page 233, should be carried out upon samples of all *raw milks* received for concentration at the factory, in order that the original supplies may be bacteriologically checked. The tests are:

(a) Bacterial Count.
(b) *Bacillus Coli* Estimation.
(c) Methylene-blue Reductase Test.

(*d*) Resazurin Test.
(*e*) Fermentation Test.
(*f*) Acidity Test.
(*g*) Sediment Test.

(*a*) *Bacterial Count*.—While the *plate count* is useful, it possesses the great disadvantage of not providing the information required within a short space of time. It cannot be used to eliminate unsatisfactory milk from the incoming supply, as the plates must be incubated for two days, while, in addition, the apparent count is invariably lower than the true count because of the fact that certain organisms do not find the media suitable for their development. In spite of the shortcomings of this method, the milk of all producers should be examined periodically in this way, in order that their supplies may be eliminated if they continue to transmit unsatisfactory milk. The examination is carried out in the following manner. Dilutions of 1 in 10, 1 in 100, 1 in 1,000, and 1 in 10,000 are made in 6-inch by ⅝-inch sterile test-tubes, the milk being mixed in a measured quantity (9 mls.) of sterile saline. One millilitre of each dilution is placed in a sterile Petri dish. Tubes of nutrient agar media, each containing 15 mls., are melted in a water bath and poured over the milk at a temperature of 45° C. The milk and the media in each dish are mixed by a rotary motion of the dish, and, when the media has hardened, the plates are inverted and incubated for two days at 37° C. At the end of this period, the plates are removed and the colonies counted, the total number of colonies on any plate being multiplied by the appropriate dilution.

The *direct microscopic count* is carried out by spreading 0·01 ml. of milk over an area of 1 square centimetre on a glass slide. The material is fixed and stained with Newman's stain, which also removes the fat. The smear is then examined microscopically, the instrument being so adjusted that the area of the field is 1/3,000 square centimetre. The number of organisms in each field multiplied by 300,000 gives the bacterial content of the milk per millilitre. A number of fields are counted and an average taken. The advantages of this method are:

(*a*) Speedy results are obtained.
(*b*) No glassware or media need be prepared.
(*c*) Cost is low.

(*b*) *Bacillus Coli Estimation*.—The dilutions employed for the plate count are again used for this test. Six double tubes each containing 10 mls. of MacConkey broth are required, five of these being inoculated as follows:

Tube 1: 1 ml. of milk.
Tube 2: 1 ml. of the 1 in 10 dilution.
Tube 3: 1 ml. of the 1 in 100 dilution.
Tube 4: 1 ml. of the 1 in 1,000 dilution.
Tube 5: 1 ml. of the 1 in 10,000 dilution.

One tube is left uninoculated as a control. The tubes are incubated for two days at 37° C. If coliform organisms are present, the media will become acid, while gas will be present in the inverted fermentation tube.

(*c*) *Methylene-blue Reductase Test*.—This test is of great importance, particularly as it has received the approval of the Ministry of Health for use in the examination of raw, designated milks. Ten millilitres of the milk to be

tested are placed in a graduated tube and 1 ml. of methylene-blue solution is added. A separate tube is used for each supply to be tested. The tubes are stoppered and inverted, after which they are incubated in a thermostatically controlled water bath at a temperature of 98° F. The tubes are inverted at half-hourly intervals. Immediately the colour has been discharged from the milk, the time is noted. The recommended standard of grading is as follows:

Grade 1: *Good milk*—not decolorised in five hours.

Grade 2: *Fair milk*—decolorised in less than five hours but not in less than two hours.

Grade 3: *Bad milk*—decolorised in less than two hours.

Grade 4: *Very bad milk*—decolorised in less than twenty minutes.

(*d*) *Resazurin Test.*—On account of the speedy result provided, this test has superseded the reductase test as a means of determining the quality of milk entering the plant. The brief details as to technique are set out on page 59.

(*e*) *Fermentation Test.*—This test is often used in conjunction with the reductase test. Tubes of milk, one for each sample, are incubated at 38° to 40° C., the coagulum which forms being examined for the presence or absence of gas bubbles and digestion of the curd. If large numbers of coliform organisms or lactose fermenting yeasts are present, a gassy curd will result. A large, mixed bacterial content may inhibit the gas-producing organisms, thus rendering the result unreliable.

(*f*) *Acidity Test.*—The method of conducting this test has already been fully described on page 99. Most condenseries reject milk showing a higher titrable acidity than 0.18 per cent.

(*g*) *Sediment Test.*—In order to estimate the quantity of visible dirt present in the raw milk, 1 pint of the fluid is pumped through a small circular cotton-wool filter pad. The pad is compared with a standard series of pads.

(2) **Condensed Product.**—Sweetened condensed milk is not sterilised during any part of its processing, and may therefore contain large numbers of bacteria. There is no legal bacteriological standard for this product, and while it would appear an open question as to whether such a standard is practicable, it would certainly seem desirable, particularly if the raw milk were efficiently pasteurised prior to concentration. The following examinations are usually made:

(*a*) Microscopic Examination of Sediment.

(*b*) Bacterial Count.

(*c*) *Bacillus Coli* Estimation.

(*a*) *Direct Microscopical Examination of Sediment.*—The milk is mixed with sterile water and centrifugalised for twenty minutes, in order to separate the fat. The fat and the supernatant fluid are drawn off and the deposit remixed with sterile water. The liquid is again centrifugalised for a similar period. The deposit is spread on a slide, fixed and stained. It is possible in this way to obtain some idea of the number of viable and non-viable organisms present, and also an approximation of the number of yeasts.

(*b*) *Bacterial Count.*—Either the plate count or the direct microscopic method of examination, or both, may be employed to determine the number of organisms present.

The *plate count* is the usual method of estimating the number of bacteria present. The lid of the can is sterilised to destroy any organisms which may be present thereon, following which the can is opened by means of a sterilised can opener, a sterile pipette being inserted to stir the contents. Ten millilitres of the milk are withdrawn from the centre of the can and transferred to a dilution bottle containing 90 mls. of sterile water. Other dilutions are prepared from this, the subsequent procedure being similar to that already set out on pages 53 and 54. The number of living yeasts is sometimes enumerated, glucose agar plates being incubated at 22° C. for this purpose (see pages 163 and 223).

The *direct method* is carried out in the following manner. The can is sterilised and opened as previously described, 0·25 ml. of milk being removed by means of a sterile pipette and mixed with 0·25 ml. of glucose agar on a sterile glass slide, the mixture being spread while warm over an area of 4 square centimetres. The slide is incubated in a moist chamber at 37° C. for eight to sixteen hours, thoroughly dried, fixed, and stained with one-quarter strength methylene blue. The number of colonies in one microscopic field is counted and the final result obtained by calculating the number of organisms present, each colony representing one original organism (see page 252 for method of calculation). This method, while only yielding a rough estimation, provides a speedy result.

(c) *Bacillus Coli Estimation.*—This examination is particularly important, as the presence of *Bacillus coli* and its allied lactose-fermenting organisms shows that the preheating process has been insufficient to kill the non-sporing and possibly pathogenic organisms present in the original raw milk. It also shows that the milk may have become recontaminated after the processing, as a result of dirty methods or surroundings. The dilutions prepared for the plate count are used for this purpose. Tubes are inoculated with 1 ml. of the whole milk, 1 in 10, 1 in 100, and 1 in 1,000 dilutions, and incubated as described on page 252. The presence of these organisms indicates that the cans from the batch require careful investigation and that the methods of manufacture call for a critical inspection.

Chemical Examination

(1) **Raw Supplies.**—The raw milk, upon receipt at the condensery, is examined for:

(a) Fat Percentage.
(b) Solids-not-fat Content.

(a) *Fat Percentage.*—For routine purposes, the *Gerber* method of estimating the fat content of the milk is used. Eleven millilitres of milk are run into the Gerber tube, followed by 1 ml. of amyl alcohol and 10 mls. of sulphuric acid (s.g. 1·83). The remainder of the procedure has already been described on page 100.

(b) *Solids-not-fat Content.*—The solids-not-fat content is calculated by means of the "*Richmond*" or "*Collins*" slide rule. The "*Richmond*" scale is based on Droop Richmond's formula, which is—

$$T = 0.25G + 1.2F + 0.14.$$

where T = Percentage of total solids.
G = Lactometer reading in degrees (corrected to 60° F.).
F = Percentage of butter-fat.

The percentage of total solids may be calculated from this formula, or from the "Richmond" or "Collins" scales which are based upon it.

(2) **Condensed Product.**—The chemical examination of the finished product is of considerable importance, since it acts as a corollary to bacteriological analysis. It is also valuable from the point of view of the nutritional importance which it yields. The usual examinations carried out are for:

(a) Fat.
(b) Total Solids.
(c) Ash.
(d) Proteins.
(e) Cane Sugar.

(a) *Fat Percentage.*—This is obtained by the *Roese-Gottlieb method.* The can containing the sample is heated by placing in warm water. This is most important in the case of sweetened condensed milk, in order that any sugar crystals which may have crystallised out of the solution can be dissolved. The temperature of heating should not exceed 110° F. The solution is allowed to cool to 60° to 70° F. and is thoroughly mixed. Four grams of the milk are weighed into a small beaker and the remainder of the test is carried out in a similar manner to that described for the estimation of the fat percentage of ice-cream (see page 56).

The *Gerber method* for estimating the fat percentage has been modified by Stanworth in the following manner. Fifty grams of condensed milk are placed in a 250 mls. flask and 75 grams of hot distilled water are added. The flask and its contents are placed in a water-bath for about ten minutes, a vigorous shaking being applied at intervals until all the sugar content has dissolved. The solution is then cooled to 60° F., a vigorous shaking being applied to ensure proper mixing. The Gerber test is then carried out in the normal way, acid with a specific gravity of 1·8 being used. The tubes are centrifuged for three minutes, placed in water with a temperature of 170° F. for five minutes, and re-centrifuged for a further three minutes. To find the butter-fat content, the following formula is used:

$$\text{Butter-fat} = \frac{2 \cdot 58 \text{ Gerber Reading}}{1 + 0 \cdot 027124 \text{ Gerber Reading}}$$

(b) *Total Solids.*—Approximately 25 grams of dry acid-washed sand is weighed into a stainless steel dish of about 3 inches diameter. The dish should contain a short glass stirring rod of length short enough to permit the closure of the lid, but long enough to rest against the side without falling into the sand. Three grams of evaporated milk or 1·5 grams of sweetened condensed milk should be accurately weighed into the dish, adding same to one side, after gathering the sand to the other. Sufficient distilled water is added to give a stiff paste on stirring with the milk and sand. The dish and contents are heated on a water bath, stirring periodically to break apart lumps. The contents are then heated in a water oven to a constant weight, the lid of the dish being closed before cooling in the desiccator. The operation usually takes 2½ hours. The total solids percentage is calculated from the final and the original weights.

(c) *Ash.*—Weigh 3 grams of evaporated milk or 1·5 grams of sweetened condensed milk into a porcelain dish, preferably of the flat-bottomed type.

The contents are dried off in a water bath, the dried material being charred carefully over a low bunsen flame. Heating is continued at a dull red heat until the residue is white in colour. The percentage of ash is calculated from the final and original weights.

(d) *Proteins.*—Twenty millilitres of the diluted milk prepared by diluting 10 grams of the condensed milk in water, the whole being made up to 100 mls., are used for the determination of the proteins, the percentage of nitrogen being estimated by the Kjeldahl method described on page 57. The percentage of nitrogen multiplied by 6·38 gives the percentage of protein.

(e) *Cane Sugar.*—Forty grams of condensed milk are transferred to a 200-mls. graduated flask with about 50 mls. of hot distilled water. The volume is made up to 120 mls. with cold water, and the mixture cooled to room temperature. Five millilitres of dilute ammonia solution (one volume of concentrated ammonia solution to ten volumes of water) are added, well mixed in and the liquid allowed to stand for fifteen minutes in order to stabilise the birotation of lactose. Sufficient dilute acetic acid is then added to be equivalent to the ammonia and the solution is again gently agitated to mix. The protein is then precipitated by the addition of 12·5 mls. of zinc acetate solution (21·9 grams of zinc acetate crystals plus 3 mls. glacial acetic acid, made up to 100 mls. with water). The whole is mixed and 12·5 mls. of potassium ferrocyanide solution (10·6 grams in water made up to 100 mls.) are added. The contents of the flask are made up to 200 mls. by the addition of distilled water at 20° C., the flask is stoppered and shaken vigorously. After being allowed to stand for fifteen minutes, the contents are filtered through dry filter paper into a dry flask, the first 25 mls. of filtrate being rejected. The rotation of this filtrate is then determined at 20° C. (=D).

The remainder of the filtrate is inverted by taking 40 mls. in a 50-mls. graduated flask, adding 6 mls. of 6·34 normal hydrochloric acid, and immersing in a water bath at 60° C. for twelve minutes with occasional agitation. The liquid is cooled and made up to 50 mls. with distilled water at 20° C. This is allowed to stand for one hour and is then polarised at 20° C. to obtain the invert reading (=I), sodium light being used. To calculate the amount of cane sugar, the following formula is employed:

$$\text{Percentage} = \frac{D - (\frac{5}{4} \times I)}{0\cdot 8825} \times \frac{200 - v}{l \times w}$$

where w = weight of condensed milk in grams.

  l = length of tube in decimetres.

  v = protein correction which equals

$$\frac{w}{100} (\text{Fat} \times 1\cdot 08 + \text{Protein} \times 1\cdot 55)$$

LEGISLATIVE CONTROL

The legislation governing the production and sale of condensed milk is similar to that already enumerated in previous chapters, with certain important additions. The legislation previously outlined is enumerated below, together with the pages upon which the appropriate sections are to be found.

In addition to the summarised legislation set out above, special Regulations known as the Public Health (Condensed Milk) Regulations, 1923 and 1927, apply to condensed milk. A war-time Order applying to this substance is the Condensed Milk (Control and Maximum Prices) Order, 1943, which prescribes a special class of condensed milk. These are as follows:

Public Health (Condensed Milk) Regulations, 1923

Definitions: "Condensed Milk" means milk or skimmed milk which has been concentrated by the removal of part of its water, with or without the addition of sugar, and includes the article commonly known as "dried milk" or "milk powder."

"Skimmed Milk" includes separated or machine-skimmed milk.

"Gross Weight" of a tin or other receptacle means the weight of the tin, etc., and of its contents.

"Importer" includes any person who, whether as owner, consignor or consignee, agent or broker, is in possession of or entitled to the custody or control of any condensed milk brought from a place situate outside the United Kingdom, the Channel Islands, and the Isle of Man. Percentages shall be calculated by weight.

Duty of L.A. to carry out Regulations.—Article 3. Duty of the Local Authority to carry out Part 1 of the Regulations.

Defines Labels and Composition.—Article 4. A person shall not sell or expose for sale or despatch or deliver to any purchaser any condensed milk intended for human consumption unless—

(1) The milk is contained in a tin or other receptacle which is labelled in accordance with the rule of the *First Schedule* to the Regulations, and contains not less than the appropriate percentages of milk-fat and milk solids as under:

Description of Condensed Milk.	Percentage of Milk-fat	Percentage of all Milk Solids including Fat
(1) Full Cream, Unsweetened . .	9·0	31·0
(2) Full Cream, Sweetened . .	9·0	31·0
(3) Skimmed, Unsweetened . . .	—	20·0
(4) Skimmed, Sweetened . . .	—	26·0

Provided that—

(a) The provisions will not apply where the condensed milk is intended to be exported or is contained in a tin or other receptacle the gross weight of which exceeds five pounds; and

(b) Where in any public refreshment-room, restaurant, shop, or other public premises condensed milk is supplied for consumption on the premises, the receptacle shall not require to be labelled.

Sampling.—Article 5. (1) Samples may be taken by Medical Officer of Health or person authorised by him or Local Authority in writing for analysis by public analyst. Seller must be notified that sample is to be analysed.

(2) Except where sample is taken for testing the quantity of milk or skimmed milk of which the contents of a tin or other receptacle are the equivalent, the sample must be divided into three parts in the usual manner and other provisions

of the Food and Drugs (Adulteration) Act, 1928, regarding the procuration of samples must be carried out.

Right of Entry.—Article 6. Gives right of entry to authorised officers to premises where condensed milk is prepared, packed, or stored and to inspect processes carried on there and to take samples of every article used in the preparation of condensed milk and of labels for affixing to tins and receptacles.

Unsatisfactory Consignments.—Article 7. If the report of the analyst states that a consignment of condensed milk in the district does not comply with the Regulations and is intended for human consumption, the Local Authority must endeavour to trace where it was manufactured and labelled. If this place is within England or Wales, the Local Authority must communicate the facts to the Local Authority for the district concerned. If the place is outside England or Wales, the facts must be communicated to the Ministry.

Customs and Excise.—Article 8. Officers of Customs and Excise may take samples of imported condensed milk, and forward them for analysis. Analyst to send portion of sample to importer. If an offence has been committed, facts to be communicated to Ministry.

Prohibition of Importation.—Article 9. Condensed milk is prohibited from being imported unless contained in a can or receptacle labelled in accordance with the First Schedule, and if it contains less than the legal standard of fat and total solids its entry can be refused. Does not apply to condensed milk which is to be re-exported or is contained in receptacles whose gross weight exceeds five pounds.

<div align="center">FIRST SCHEDULE.</div>

Rules with respect to the Labelling of Condensed Milk.

(1) This paragraph has now been repealed by the Amending Regulations of 1927, and deals with the labelling of tins of milk.

(2) The declaration shall in each case be completed by inserting at (*a*) the appropriate number in words and figures, e.g. "one and a half ($1\frac{1}{2}$)," any fraction being expressed as eighths, quarters, or a half. For the purpose of these Rules, milk means milk which contains not less than 12·4 per cent. of milk solids (including not less than 3·6 per cent. of milk-fat), and skimmed milk means milk which contains not less than 9 per cent. of milk solids other than fat.

(3) This paragraph has now been repealed by the Amending Regulations of 1927 and deals with the type and layout of the declaration to be printed on tins of condensed milk.

(4) The label shall, in addition, bear the name and address of the manufacturer of the condensed milk or of the dealer or merchant in the United Kingdom for whom it is manufactured.

(5) The label shall be securely fixed to the tin or other receptacle so as to be clearly visible. If there is attached to the tin or other receptacle a label bearing the name, trade-mark, or design representing the brand of condensed milk, the prescribed declaration shall be printed as part of such label.

(6) There shall not be placed on any tin or other receptacle containing condensed milk—

(*a*) Any comment on, explanation of, or reference to the statement of equivalence contained in the prescribed declaration or the words "machine-skimmed," "skimmed," or "unfit for babies"; or

(*b*) Any instructions as to dilution, unless either—

(i) The fluid produced in accordance with such instructions would contain not less milk-fat and not less milk solids than milk or skimmed milk as defined in Rule 2 of this Schedule as the case may require; or

(ii) Such instructions clearly specify that the fluid so produced is not of equivalent composition to milk or skimmed milk, as the case may be.

(7) Where the word milk appears on the label of a tin or other receptacle containing condensed skimmed milk as part of the description of the contents, it shall be immediately preceded by the words "machined-skimmed" or "skimmed," as the case may require.

Public Health (Condensed Milk) Amendment Regulations, 1927

These Regulations amend those of 1923. The two following Articles are the most important in the Regulations.

Article 3.—The following provision shall be added to and form part of the principal Regulations immediately after Article 4 thereof; that is to say—

"4a—Where a tin or other receptacle containing condensed skimmed milk is required by Article 4 of these Regulations to be labelled, no person shall expose or offer for sale such tin or receptacle in a paper or other wrapper unless such wrapper has printed on the outside thereof the words 'unfit for babies,' such words being contained within a surrounding line. The type used for the words shall not be less than a quarter of an inch in height and the printing shall otherwise conform with the rules prescribed for the printing of the same matter on the label affixed to the tin or other receptacle."

Article 4.—The following paragraphs shall be substituted for paragraphs 1 and 3 of the First Schedule to the principal Regulations:—

(1) Every tin or other receptacle containing condensed milk shall bear a label upon which is printed such one of the following declarations as may be applicable or such other declaration substantially to the like effect as may be allowed by the Minister:

(ii) In the case of full-cream milk (sweetened):

CONDENSED FULL-CREAM MILK, SWEETENED
THIS TIN CONTAINS THE EQUIVALENT OF (a) PINTS OF MILK, WITH SUGAR ADDED

(iv) In the case of skimmed milk (sweetened):

CONDENSED MACHINE-SKIMMED MILK (or CONDENSED SKIMMED MILK), SWEETENED

UNFIT FOR BABIES

THIS TIN CONTAINS THE EQUIVALENT OF (a) PINTS OF SKIMMED MILK, WITH SUGAR ADDED

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(3) (*a*) The prescribed declaration shall be printed in dark block type upon a light-coloured ground.

(*b*) There shall be a surrounding line enclosing a declaration and in the cases in which the words "unfit for babies" are required to be used there shall be another such line enclosing those words.

(*c*) The distance between any part of the words "unfit for babies" and the surrounding line enclosing those words shall not be less than one-sixteenth of an inch.

(*d*) No matter other than that hereinbefore prescribed shall be printed within either surrounding line.

(*e*) The type used for the declaration shall not in any part be less than one-eighth of an inch in height (or if the gross weight of the tin or other receptacle does not exceed twelve ounces, one-sixteenth of an inch in height) and the type used for the words "unfit for babies" shall not be less than twice the height of any other part of the declaration.

The words "**UNFIT FOR BABIES**" have now been replaced by the words "**NOT TO BE USED FOR BABIES**," as set out in Circular 2830 of the Ministry of Food, dated July, 1943.

The Condensed Milk (Control and Maximum Prices) Order, 1943

This regulation makes provision for the control and sale of condensed milk, prohibiting sale, or delivery on sale, of any condensed milk manufactured by any firm, except under licence from the Minister of Food. A special class of condensed milk is introduced which must not contain less than 10 per cent. of milk-fat.

CHAPTER VI

EVAPORATED MILK

Introductory

UNSWEETENED condensed milk is generally known as evaporated mi
is obtained in practically the same manner as the sweetened variety
though the process varies only in certain minor details, this milk d
from sweetened condensed milk in that no sugar is added as a preservi
Evaporated milk is merely fresh cow's milk from which approxim.
65 per cent. of the water content has been removed. To effect preservat
the product is sterilised by heat after concentration, and is sold in
hermetically sealed cans in which it has been sterilised.

Although evaporated milk is classified as condensed milk by legislation,
it is obvious, from the treatment which it receives, that it is not the same
product. Nothing is added to evaporated milk, while nothing is lost except
the major portion of its water content. In addition, the only means of
preservation is heat, which, incidentally, imparts a characteristic and readily
noticeable flavour to the finished article.

History

Evaporated milk was first produced to meet an increasing demand for
pure milk which would keep for lengthy periods. The process was first
invented by John Meyenberg, a native of Switzerland. He patented his
method of evaporating milk in 1884, after which date it was further developed
in conjunction with Louis Latzer. A company was formed in 1885, known as
the Helvetia Milk Condensing Company, the factory being situated at
Highland, Illinois, U.S.A. This was the first company to manufacture
evaporated milk which was unsweetened, sterilised by heat, and sold in
hermetically sealed cans.

The improvement of the vacuum pan by Gail Borden in 1856 rendered
the preparation of both condensed and evaporated milks possible. The
years which have passed since this date have been marked by considerable
activity, as many obstacles which presented themselves had to be overcome.
It is, of course, a fact that much of the milk so treated in those early days
would be unrecognised as evaporated milk to-day. Constant scientific
experiments have resulted in enormous improvement, and it can now be
stated with almost certain assurance that the manufacture of evaporated
milk is as perfect as science can make it. It has been of inestimable benefit
to the inhabitants of these islands during the War which has just ended.
Large quantities of evaporated milk have been imported to alleviate the
shortage of liquid milk due to war conditions.

Composition

The composition of the finished product varies according to whether it
is produced from whole or skimmed fresh milk. Very little evaporated
skimmed milk is produced in this country. Below is given an average
analysis of each type of evaporated milk:

					Evaporated Whole-milk	Evaporated Skimmed Milk
Total solids	.	.	.	.	32·53	23·38
	.	.	.	.	9·10	0·75
	.	.	.	.	1·94	1·78
	.	.	.	.	8·75	8·35
	.	.	.	.	12·74	12·50
	.	.	.	.	67·47	76·62

porated milk or, as it is legally termed, unsweetened condensed must comply with certain standards as regards the percentage of fat otal solids including fat. Below are given the standards for this y and those required in the United States of America.

				Percentage of Milk-fat	Total Solids
Great Britain					
(a) Full Cream (Unsweetened)	.	.	.	9·0	31·0
(b) Skimmed (Do.)	.	.	.	—	20·0
(2) United States of America					
(a) Full cream (Unsweetened)	.	.	.	7·8	25·5
(b) Skimmed (Do.)	.	.	.	—	20·0

It will be seen from these figures that the standard in Great Britain is more stringent than is the case in America. Emergency legislation issued during the War in this country, has reduced the milk-fat and total solids content of full-cream unsweetened evaporated milk to the standard applicable in the United States of America.

Food Value

Evaporated milk will keep indefinitely as a result of the sterilisation process. The food value of sweetened condensed milk has already been discussed on pages 228 to 230, and the facts stated there apply with equal force to evaporated milk. There are, however, certain additional facts concerning this type of milk, such as changes brought about by the high temperatures used at certain stages of the process. The lactose or milk sugar is often caramelised or burnt during sterilisation. This gives the product a slightly brownish tinge, besides imparting that peculiar flavour which is at once apparent to the palate. The absence of any cane sugar reduces the food value of the product to a certain extent, but the article should not be essentially different in this respect from raw milk. The fat in cow's milk and in sweetened condensed milk is present in large globules, and infants find it much more difficult to digest. To correct this, the fat globules in evaporated milk are broken up into minute particles by the homogenising process. The proteins of the milk are coagulated by the temperatures attained, but, as indicated on page 231, there is little evidence to show that such coagulation exerts any detrimental influence upon the product or affects its digestibility in any way. Indeed, in the case of egg albumen, heat coagulation increases its digestibility, and it is possible that this also applies to the proteins of evaporated milk. With regard to the vitamins, it is probable that only vitamins A and C are in any way affected by the process, those particular substances being exceedingly susceptible to oxidation.

Evaporated milk is a valuable food for infants, but is not complete in itself, the addition of orange or tomato juice, limewater or barley water, being necessary to provide an adequate, composite diet. Apart from human

milk, cow's milk is without doubt the best food for infants, yet even this requires to be modified and supplemented with other foods if the child is to have a properly balanced diet. The fat in human milk remains in an emulsion, as the fat globules are in such a state of atomic minuteness that they cannot rise to the surface even if the milk is allowed to stand. Cow's milk possesses larger fat globules, which, as previously mentioned, are mor difficult to digest. The homogenisation process applied to evaporate milk produces the minute fat globules which are characteristic of human milk. Because of the heating incident upon its preparation, the curds of evaporated milk are small and flocculent, and are easily digested and assimilated. If a suitably balanced diet is given in addition to evaporated milk, a further recommendation would be the product's sterility, although this is unfortunately not always the case. As with sweetened condensed milk, the manufactured product contains proteins, abundant fat, present in an easily assimilable form, and mineral salts.

Because of its indefinite keeping qualities, evaporated milk is employed for a variety of purposes in addition to infant feeding. It is used by explorers, ships' crews, and others who are out of touch with civilisation and therefore unable to obtain supplies of fresh milk. In the household, it is in great demand as a source of creamy, smooth, and finely textured puddings, sauces, and gravies. This is due to the breaking up of the butter-fat and the increased viscosity following the homogenisation process, which enables the milk to blend perfectly when combined with other ingredients. It is extensively used in coffee in lieu of cream, for whipping purposes, and for cocoa, chocolate, or tea. It is also used in place of fresh cream with fruit, for the manufacture of ice-cream, and for confectionery purposes. In addition, the flavour of certain foods is definitely enhanced by its use.

Commercially, the milk is widely used by bakeries, confectioners, chocolate and sweet-makers, by ice-cream manufacturers, and in restaurants and institutions. It can be diluted with milk or cream to produce coffee cream, and in America is a national article of everyday diet.

Evaporated Milk and Disease

Few definite outbreaks of disease have been traced to the consumption of evaporated milk. In two instances, outbreaks of botulism have been reported from the United States of America, due to the consumption of spoiled canned milk which was infected with *Clostridium botulinum*.

Effect of Heat

The effect of heat on milk has already been discussed in Chapter V, pages 230 and 231. Higher temperatures are used in the preparation of evaporated milk than is the case with most other milk products. As regards the bacterial content, it is the aim of the manufacturer to produce an article which is quite sterile, and it is a fact that approximately 80 per cent. of cans containing this product will be found in such a condition. It is, of course, a comparatively easy matter, given the requisite time and temperature, to produce a sterile article which will keep indefinitely in a sealed can. In practice, however, the manufacturer has no wish to over-process the milk, since, because of the differences in temperatures of sterilisation, the product may either become coagulated or useless, while the food value may be destroyed almost in its entirety. A tendency therefore exists to

underheat the product, which practice does not ensure a sterile article in every case. In this connection, Savage has investigated samples of this type of milk and has found that 80 per cent. of the cans examined were sterile, while the remainder contained spore-bearing bacteria which had survived the processing temperature, although no outward appearances or signs of decomposition were noticeable in the cans.

The chemical changes already referred to in Chapter V also occur in this type of milk, with certain additions. The lactose, for instance, is definitely caramelised and becomes brown in colour at temperatures of 175° F. and above. This accounts for the light buff colour of evaporated milk. In addition, the acidity of the product is increased, as lactose is a source of acidity during the heating process.

Manufacturing Process

The manufacture of evaporated milk is a lengthy process, carried out in the following stages:

(1) Preparation of the Milk.
(2) Forewarming.
(3) Condensing.
(4) Superheating.
(5) Homogenising.
(6) Cooling.
(7) Filling and Sealing.
(8) Sterilisation.
(9) Sterilisation of Plant.

It may be stated here that skimmed, evaporated milk is processed in a similar manner to that of the full-cream product.

(1) **Preparation of the Milk.**—The raw milk used in the preparation of evaporated milk is treated in a similar manner to that which applies in the case of sweetened condensed milk, as discussed on pages 232 and 233. It is essential that the raw milk should be of the highest quality in order to ensure that the resultant product is as free as possible from heat-resisting organisms. Only really fresh milk can be used, since, if the acidity of evaporated milk is above normal, it will clot during sterilisation and will thus be rendered unsaleable.

On receipt at the factory, the milk is sampled, weighed, clarified, and cooled, after which it is run into storage tanks. The tests made from each batch are:

(a) Flavour test.
(b) Fat percentage test.
(c) Solids-not-fat content.
(d) Acidity percentage.
(e) Sediment test.
(f) Methylene-blue reductase test.
(g) Fermentation test.
(h) Alcohol test.

This latter test is of particular importance as it provides the most convenient means of assessing the heat-stability of the incoming milk. Five millilitres of milk to be tested are added to an equal quantity of 75 per cent.

alcohol in a small test tube which is then stoppered. The tube and its contents are inverted twice and then examined. If coagulation takes place it is concluded that the milk possesses a low heat-stability and it should be rejected as unsuitable for processing. The test is inexpensive to carry out and is simple and rapid in execution. Heat-stability is influenced by the relative amounts of mineral salts present in milk. Milk possessing excess of calcium and magnesium salts in relation to the phosphates and chlorides present will have a low stability, while, conversely, a milk in which the phosphates and the chlorides are in excess over the calcium and magnesium salts, will possess high heat-stability. Other conditions affecting heat-stability are the acidity which has developed in the milk and its albumin content.

Samples are taken for the estimation of the bacterial content at regular intervals, and for the presence of coliform organisms. The methods employed in conducting these tests have already been described on pages 53 to 55 and 252. The milk is weighed, filtered and cooled and then passed to storage. During the time the milk is in the storage tanks, it is standardised to the required fat and solids-not-fat content. This operation is exceedingly important.

(2) **Forewarming.**—The milk is forewarmed in a similar manner to that described on pages 233 to 236. The temperature at which the operation is carried out is most important, by reason of the fact that the product is liable to coagulate during the sterilising process. The temperature at which coagulation occurs is influenced by several factors, of which the forewarming of the milk is one of the most important. Several investigators have reported that the coagulability of fresh-milk samples from individual cows varies considerably. In mixed milk, the variation in the fresh-milk samples is not so great, but variations in the evaporated product of such milk may be considerable. It appears, therefore, that there is no correlation between the coagulability of fresh milk and that of the evaporated article produced therefrom. In addition, the stability of the evaporated article becomes progressively less as the solids are in-
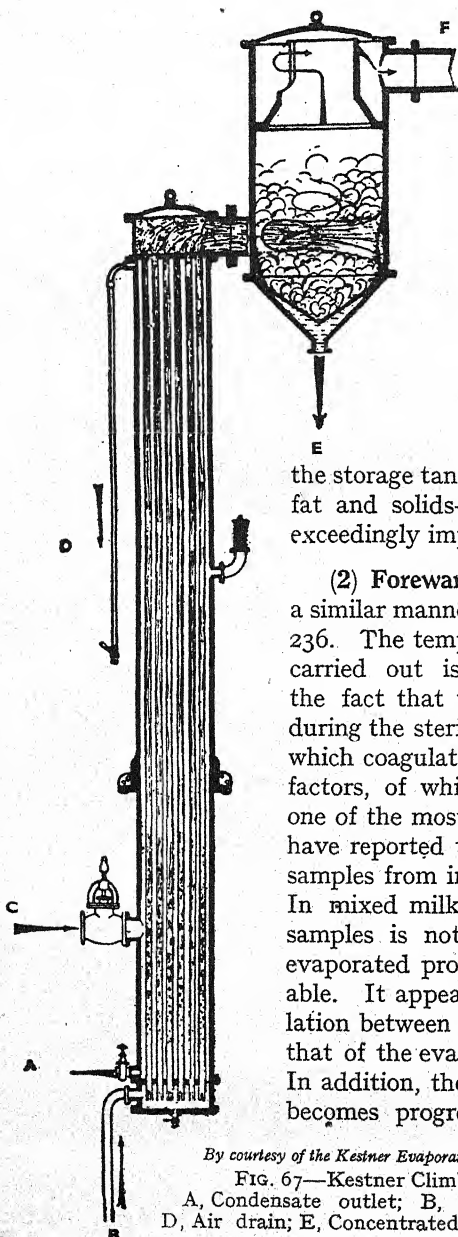
By courtesy of the Kestner Evaporator & Engineering Co., Ltd.

FIG. 67—Kestner Climbing Film Evaporator (Section)
A, Condensate outlet; B, Liquid inlet; C, Steam inlet valve; D, Air drain; E, Concentrated liquid outlet; F, Vapour outlet.

creasingly concentrated. The growth of lactic-acid organisms in the milk, with a corresponding rise in acidity, usually results in a lowering of the temperature of heat coagulation. If, however, the calcium content is lower than normal, the acidity which develops will raise the coagulation temperature by bringing more calcium into solution.

The two main factors which control heat coagulability are:

(a) The albumin content of the milk.
(b) The balance of the mineral salts.

The greater the albumin content, the lower will be the temperature of coagulability. The calcium and magnesium salts of milk balance the phosphate and citrate content. If this balance is in any way disturbed, the temperature of coagulation will be lowered. If the temperature of the milk is varied until coagulation occurs, calcium and magnesium are precipitated as phosphates and citrates and a visible curd appears. It has been found in practice that a forewarming temperature of 149° F. lowers stability, whereas a temperature of 203° F. or above affords an appreciable increase in stability, this effect being more pronounced if the milk is held at such temperatures for a short period. The temperature-stability curve of evaporated milk is the reverse of that of sweetened condensed milk, owing to the effect exercised by the added sugar. The forewarming temperature used varies from 230° to 240° F., as temperatures above boiling point, while increasing stability, cause the final product to be dark and to possess a reduced viscosity. The forewarming process usually occupies about twenty minutes, the milk being maintained under pressure to prevent any tendency for it to burn on the tubes. In addition, high-speed circulation through the tubes is also essential. This appears to result in the production of a more satisfactory article. In addition, the high temperatures used result in a greater freedom from micro-organisms prior to condensing. Most
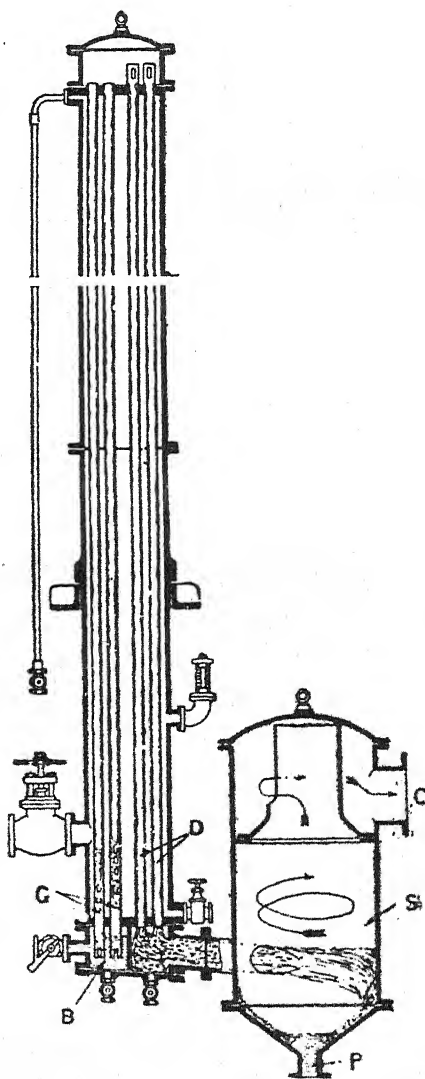
By courtesy of the Kestner Evaporator & Engineering
Co., Ltd.

FIG. 68—Kestner Falling Film Evaporator

B, Liquid inlet box; G, Climbing film tubes; D, Falling film tubes; S Separator; C, Vapour outlet; P, Concentrated liquid outlet.

S

samples of evaporated milk will survive a sterilisation temperature of 240° F. applied for fifteen minutes, without any coagulation of the contents. An appreciable number, however, will not do so and, in order to prevent the loss of whole batches through this cause, a proper understanding of the factors controlling the heat coagulation of milk is essential. It is the usual practice to add between 4 ozs. and 12 ozs. of sodium bicarbonate to the milk to act as a stabiliser, when manufactured in this country. Di-sodium phosphate or sodium citrate is used for this purpose in American practice.

(3) **Condensing.**—The method of vacuum-pan operation very closely resembles that used in the preparation of sweetened condensed milk, dealt with on pages 237 to 243. There are, however, several minor deviations. In the first place, it should be remembered that, while the degree of concentration in this country is greater than that required in the United States by reason of the higher fat and solids-not-fat standard normally demanded, the milk is not concentrated to the same degree as sweetened condensed milk. One further point which requires mention is the likelihood of foaming. This occurs more frequently with unsweetened milk, and care should be taken to reduce this to a minimum. The concentration process occupies two and a half hours, the original raw milk being reduced 40 per cent. in bulk. The milk is usually prepared to a specific gravity of 1 : 10, but this may vary with the fat content and the desired concentration.

The present tendency in the manufacture of evaporated milk is to work on continuous lines as this particular product lends itself to this method of processing. A tubular type of calandria pan, as shown in Fig. 63, possesses one considerable advantage in that the amount of milk in the pan at any one time is much less than is the case with the normal coil-type pan. In connection with continuous processing, widespread use is being made of the thermo-compression system which is usually applicable to the calandria type of pan. When this system is employed the vapour evolved from the boiling milk is partially entrained by a jet of pressure steam, and the vapour arising from this mixture of steam and vapour is injected into the calandria of the condenser and forms the heating medium. This heating temperature is approximately 30° F. above the boiling point of the milk. The vapour from the pan which is not entrained by the pressure jet passes to the condenser in the normal manner.

Practically, this system enables a considerable reduction to be made in the quantity of steam required for evaporation, and by using steam at a pressure of between 100 lb. and 120 lb. per square inch a reduction of approximately 50 per cent. in the quantity of steam required for evaporation may be obtained. If desired, low-pressure steam, i.e. 15 lb. to 30 lb. per square inch, from a steam engine or a turbine may be used if special apparatus is provided. More steam is consumed by this method than if high-pressure steam is employed, but the choice depends upon the power load of the condensery. A further advantage is the fact that the temperature of the heating medium is only 30° F. above the boiling point of the milk and this reduces the tendency to coagulation of the milk solids on the heating tubes.

The calandria type of pan is larger than one using high-pressure steam as the heat-transference rate is lower. Continuous running of the plant as a whole can be continued through the homogeniser and cooler, but the final product is usually standardised before canning takes place.

A novel and ingenious type of forced-circulation evaporator known as the

Kestner Climbing Film Evaporator (Fig. 67), possesses many advantages. It is continuous in operation, the milk being delivered and discharged without any interruption of the process. The milk is only in contact with the heating surface for fifty seconds, so that "stewing" is prevented. The entire operation is performed under a high vacuum, so that the milk boils at a low temperature with a complete absence of foaming. The evaporator is provided with vertical tubes, each some 23 feet in length, these tubes being surrounded with a steam jacket. Raw milk is fed into the tubes at the base, and the vapour which is released passes upwards, causing the milk to climb the walls of the tubes in a thin film at a high velocity. As the film rises, further evaporation occurs, until at the apex of the tubes the mixture of vapour and milk passes to a separate chamber, from which the vapour passes to a condenser, the milk itself being drawn off. Another type of plant known as the *Kestner Falling Film Evaporator* (Fig. 68) works in the reverse direction.

(4) **Superheating.**—It is the practice in some factories to superheat the milk in order to reduce the danger of coagulation during the sterilisation process. When this is done, the milk is superheated after concentration by means of steam, either when it is still in the vacuum pan or immediately after it has been drawn off. The object of this process is to coagulate the albumin and to precipitate part of the casein. Live steam is blown into the milk until the temperature reaches 194° to 200° F. A flaky product is apt to result, and for this reason the more modern practice is to homogenise the milk after concentration.

(5) **Homogenisation.**—Homogenisation is beneficial to the manufacture of evaporated milk, as it breaks up the butter-fat globules which are distributed homogeneously in the milk. This secures an even distribution of the casein, albumin, and lactose. Before this process was employed, the heavy solids contained in the milk settled to the bottom of the can, while the lighter portions rose to the surface, the net result being a diminution in the attractiveness of the finished article. The process causes the butter-fat globules to be surrounded by and to adhere to the albumin and casein present in the milk. The breaking up of the fat is responsible for a more perfect blending, with a resulting increased smoothness to the palate. The disintegration also renders the milk more digestible, as there is then no difficulty in assimilating the fat. This process is infinitely preferable to superheating, which, as already indicated, is used in some factories, contamination of the milk being greatly minimised. The increased viscosity of the product following homogenisation, however, lowers the temperature of heat coagulation.

The milk on leaving the vacuum pan passes to a supply tank, whence it is fed to one or more homogenisers. The usual type of apparatus is a three-throw pump, which compresses to a pressure of 2,500 to 4,000 lb. per square inch. The homogenising valve is the main feature of the apparatus, and through this the milk is forced at a pressure of 1,000 to 3,000 lb. per square inch into an area of low pressure. There are several types of valves in use. One type consists of an agate stone and a ground seat, through which the milk is forced. Other types make use of ground discs or valves. Valves should be constructed of stainless steel. The size of the opening is adjustable, varying between 3/1,000 and 1/10,000 inch. The milk should be homogenised when warm, improved results being obtained

if this is done, as the reduced viscosity of the material facilitates the working of the apparatus. A *Weir homogeniser* is illustrated on page 92.

(6) **Cooling.**—The cooling of sweetened condensed milk, as described on page 243, is an important process and, in order to effect the required degree of lactose crystallisation, must be performed under carefully controlled temperature conditions. With evaporated milk, the problem is entirely different. This type of milk should be cooled as quickly as possible, but not below freezing point, as no crystallising precautions are necessary. The water content of sweetened condensed milk is between 20 and 30 per cent. of the whole, but evaporated milk has a higher water content, which is sufficient to keep the lactose in permanent solution. The methods of cooling vary, and, in fact, any method may be used. Ordinary surface coolers are often employed for this purpose, but due precautions should be taken to ensure that contamination is guarded against. Coolers of the plate heat-exchanger type are eminently suitable, as the milk is not exposed to any contamination from the air. The final temperature is usually in the neighbourhood of 40° to 45° F.

(7) **Filling and Sealing.**—The milk passes from the cooler to the filling machine. Several machines have been designed for this purpose, one type being an almost human device which fills what is known as the "Vent Hole" can with the exact quantity of milk through a small aperture, $\frac{1}{8}$th inch in diameter. It is essential that the cans should be filled as quickly as possible after the milk has been cooled. The milk is readily contaminated either immediately after cooling or during filling operations, which provide considerable opportunities for the pollution of the product unless the greatest care is exercised. The filling machines should be kept clean and free from stale milk, and should be cleansed thoroughly after each batch of milk has been filled. After the cans have been filled they are immediately sealed. The sealing process requires care, as the seal has to withstand the heat of the sterilisation process. Whatever method is employed, care must be taken to ensure that it is adequately performed. The opening in the can is usually soldered by a mechanical finger, but hand soldering is sometimes practised. When the cans leave the sealing machine, they are tested for leaks by being plunged into a hot-water tank. If any of the tins rise or give off air bubbles, they are discarded as unfit for sale. Modern sealing processes are so rapidly carried out that a hundred cans may be sealed in one minute. What is known as the "Open" or "Sanitary" can is very often used. The milk is filled into the open can, one end of which is seamed, and after filling, the other end is seamed by an automatic seaming machine.

(8) **Sterilisation.**—Once the cans are filled, it is necessary to sterilise their contents in order to ensure permanent safety from bacteria and to endow the milk with good keeping qualities, there being no added sugar to assist preservation. The object of the process is to destroy all bacteria and enzymes, while, since spores and all vegetative forms must also be killed, the temperature employed must be well in excess of 212° F. In addition, this temperature must be maintained for a sufficient period to effect the necessary destruction. A temperature of 240° F. is usually employed. It should be remembered, however, that too high a sterilising temperature or

toolengthy a period of exposure will result in the formation of an objectionably hard curd, while the colour of the milk will also be affected.

Three systems of sterilisation are in common use, as follows:

(a) Batch.
(b) Continuous.
(c) Fractional.

(a) *Batch Sterilisation.*—This method is most popular in this country to-day. The cans on leaving the filling machine are placed in racks in a large steam-tight boiler. The racks are moved by a revolving mechanism, which keeps them in motion throughout the process, the speed of rotation varying between 6 and 12 revolutions per minute. In some instances, the racks are oscillated instead of revolved. The steriliser may be either cylindrical or rectangular in shape. The process is carried out by means of steam under pressure, the time and temperature employed depending upon the concentration, composition, and seasonal character of the milk. Steam is admitted to the steriliser until the temperature reaches 240° to 245° F. (some fifteen to twenty minutes being required), and the apparatus is maintained at this temperature for not less than fifteen minutes. Uniform distribution of heat is sometimes obtained by passing the cans through hot water in the steriliser, but this effect is more generally secured by the oscillation or revolution of the cans. This latter movement also assists in breaking up any coagulation which may have formed as the result of heating. A certain degree of coagulation is, however, desirable. This causes the product to possess an increased viscosity, which prevents separation of the fat. If the coagulum is not too thick, and is carefully broken up into a homogeneous liquid, the milk will possess a thick, creamy appearance.

The important factors in the sterilisation process are:

(i) The temperature attained.
(ii) The period during which this temperature is maintained.
(iii) The extent of oscillation during the process.

After sterilisation has been completed, the steam is shut off and the cans are cooled to 75° F., either by means of water sprays or by immersion in cold water. When cooled sufficiently to be handled, the cans are passed through an oscillating machine, which breaks up any curd formed during the process of sterilisation and retains the smooth, homogeneous texture of the milk.

(b) *Continuous Sterilisation.*—This is a comparatively recent development which allows of continuous processing. It is much used in the United States of America and considerable advances in this method of treatment have taken place during the last few years. The cans are preheated before they pass to the steriliser. This possesses a series of compartments which are maintained at different temperatures. On entering the apparatus, they roll through the sterilising chamber by means of a spiral track, which ensures that the heat distribution in each can will be identical. This rolling motion of the cans takes the place of the methods of agitation provided in the batch method, while, in addition, the heating agent is economised, there being no heating or cooling of the apparatus. After treatment has been completed, the cans pass to a cooler, which operates under similar pressure conditions to those of the steriliser.

(c) *Fractional Sterilisation.*—While this method has its ardent advocates, it also numbers many detractors. It is considered out of date in America, but is still used upon the grounds of low cost with satisfactory quality. The sealed tins are placed in a water bath at a temperature of approximately 100° F., where they remain for eight hours. The water is then allowed to cool gradually. Four hours after cooling, the water temperature is raised to 149° F. and is held at this temperature for thirty to forty minutes. The cans are finally dried and passed to storage.

Following sterilisation, it is usual to store the cans for two to three weeks, either in incubators or rooms in which a temperature of 80° F. is maintained, in order that any imperfections in the sealing of the cans or in the sterilisation process may be detected. Fermentation is quickly detected by the bulging of the cans. In addition, they are often tested by percussion on leaving the incubators. When passed as satisfactory, they are labelled and packed for despatch.

(9) **Sterilisation of Plant.**—Just as it is necessary to sterilise the milk to prevent bacterial growth, so is it necessary to cleanse and sterilise the plant and utensils in an efficient manner. All utensils and apparatus should be thoroughly washed with cold water, then with very hot water, and should finally be sterilised with steam. The methods employed in the sterilisation of plant and utensils used for the manufacture of other milk products have been fully described in previous chapters, the remarks regarding the sterilisation of condensed milk plant set out on page 245 being particularly applicable. Large quantities of evaporated milk may deteriorate or become unsaleable by reason of the growth of unwanted micro-organisms. Such losses could be prevented by employing efficient means of sterilisation.

Inspection of Cans

Mention has already been made of the methods of inspection employed at the factory, while, on page 245, the inspection methods have received more detailed consideration. It will be sufficient here to repeat the fact that cans of milk are examined externally by superficial and physical methods. Cans are sometimes opened in order to inspect the contents, the number treated in this way varying according to the individual ideas of the inspector. Cans of evaporated milk may appear sound externally, but when opened will be sour or rancid, although there may be little or no gas formation. This defect is believed to be due to the presence of enzymes in the milk which have escaped destruction. When this defect is discovered, further cans from the same batch should be inspected, as all are liable to be similarly affected. An efficient container should comply with the following requirements:

(1) Should be manufactured from well-tempered steel with a satisfactory coating of tin.

(2) Should possess a well-manufactured body.

(3) Should exhibit well-joined ends of metal to form side seam.

(4) Should have double-seamed or soldered ends.

Bacteria in Evaporated Milk

The bacteriological problems of evaporated milk are entirely different from those of the sweetened condensed variety. Owing to the methods

used in evaporation and sterilisation, the final product should, if properly processed, be perfectly sterile. When the number of times the milk is heated and the temperatures attained are considered, it will be appreciated that only organisms which are exceptionally resistant to heat will survive the processing. It can also be emphatically stated that, if suitable temperatures are reached and maintained, the spoilage of evaporated milk through the activities of bacteria will be a rare occurrence.

The sterility and keeping quality of the final product depend upon the heat treatment provided, any laxity producing subsequent trouble. In addition, the bacterial count of the raw milk and its freedom from contamination during processing are also important, since, if spore-forming or heat-resistant organisms obtain entrance in large numbers, there is a reasonable possibility that some may survive and multiply in the final product during storage. Although the sterility of evaporated milk should be a matter of comparatively easy accomplishment, it is not always attained, for the following reasons.

The most important stage in the treatment of the milk with respect to the destruction of micro-organisms occurs during the sterilising process. The temperature in the interior of the steriliser is usually checked by a thermometer and, though this may give a satisfactory reading for the entire period, it cannot guarantee that the complete contents of each can reach the requisite temperature, or that they are held at that temperature for the entire period. As a means of checking the temperature of the milk in the steriliser, cans are inserted, to which are fitted maximum thermometers. These cans are distributed throughout the apparatus and will certainly indicate whether or not the optimum temperature has been reached. They cannot, however, give any indication as to the time during which the contents of such cans have been held at that temperature. A time "lag" exists between the attainment of the external and internal temperatures of the can and its contents, the extent of such "lag" being greater than is generally realised. This has been proved by various investigators, and may result in the contents of the cans attaining the optimum temperature for only a short period. In addition, the faulty sealing of containers may also be a factor responsible for bacterial spoilage occurring after sterilisation. The sealing may not be tested in every case, while, if testing is the normal procedure, some may be overlooked.

Organisms of various types have been discovered in cans of evaporated milk by different investigators. *Aerobic, spore-forming bacteria* have been found both in sound and in unsound cans. These organisms are capable of growth in evaporated milk, but do not readily exhibit such activity. They are of little importance as a cause of gas production or unsoundness of contents, and do not clot or peptonise the milk unless present in excessive numbers. Their inactivity is due to the colloidal changes which result from concentration and sterilisation. *Anaerobic, spore-bearing organisms* are infrequently the cause of decomposition. In themselves such organisms are of little importance, but they may, in conjunction with other bacteria, decompose the milk. For this reason, their presence is most undesirable.

Gas-forming aerobes are not found in sound samples of evaporated milk. Members of this group, such as *Bacillus coli* and *Bacillus cloacæ*, are incapable of growing in and decomposing evaporated milk. They

produce gas, following which the contents of the cans become clotted. *Thermophilic bacteria* are rarely found in evaporated milk and possess little significance. *Yeasts* have occasionally been found in sound or unsound products. Non-fermenting yeasts are of little importance, but the presence of fermenting types will result in blown cans.

Micrococci, principally diplococci and streptococci, and occasionally staphylococci, have been isolated from sound and unsound containers. Their presence may cause the production of carbon-dioxide gas. Some types cause the milk to deteriorate with the production of acidity, frothiness, blowing of the can, bitterness, clotting, and in some instances the presence of a cheesy odour. *Coccoidal bacilli* have also been isolated from unsound cans. They may produce gas in sufficient quantity to blow the container.

In addition to the above bacteria, several others are the cause of abnormal conditions. These are discussed below.

Defects in Evaporated Milk

Defects in evaporated milk are due either to the presence of *abnormal micro-organisms* or to *changes of chemical or physical origin*. The principal defects caused by *abnormal micro-organisms* are:

(1) Gassy Fermentation.
(2) Coagulation.
(3) Bitterness.
(4) Fishiness.

(1) **Gassy Fermentation.**—In sweetened condensed milk, this defect is due to the presence of fermenting yeasts, but several micro-organisms may also be involved in the evaporated product. *Bacillus coli*, *Bacillus cloacæ*, micrococci, coccoidal bacilli, spore-bearing anaerobes and gas-forming yeasts have all been isolated from rejected cans, and these organisms, when inoculated into sound cans, caused them to become blown. The external appearance of the blown cans is similar to blown cans of the sweetened variety. There is sometimes a sufficient evolution of gas to distort the cans and even burst the seams.

These organisms are usually found in isolated cans, but entire batches of milk may be affected, due to the presence of heat-resistant, spore-forming organisms of the genus *Clostridium*. Such organisms give rise to gas production with the formation of acids, while the milk becomes putrid. They are carried by dust, hay, straw, and decaying matter, and the only method of prevention is to ensure the strictest cleanliness in the raw-milk supply and factory methods, together with efficient sterilisation of the plant and utensils. *Streptococcus distendens* has also been found to be the cause of fermentation in cans of evaporated milk, accompanied by the production of acid.

(2) **Coagulation.**—This defect is often found and takes the form of a hard curd, which shrinks and becomes surrounded by whey. The curd will move about when the can is shaken. The causative organism is the *Bacillus coagulans*, *Bacillus cereus*, *Bacillus calidolactis*, and similar organisms, which form considerable acid. The contents of the can possess a bitter and cheesy taste and exhibit considerable acidity. These organisms resist fairly high temperatures. Acid clots due to *lactic-acid bacteria* are sometimes found, on account of contamination after sterilisation, following faulty sealing of the cans.

(3) Bitterness.—This defect sometimes develops and causes marked acidity, together with a characteristic bitter taste. One responsible organism is the *Bacillus amarus*, while another, very similar to the *Bacillus panis*, produces acidity and bitterness, and possesses a high thermal death-point which is stated to be 250° F. for eight minutes. For this reason, it is essential that the sterilisation process should be adequately performed, while strict cleanliness in the factory is necessary if this defect is to be limited in severity.

(4) Fishiness.—Fishiness has been discovered in cans of evaporated milk, due to the presence of the *Bacillus ichthyosmius*. The presence of this organism gives rise to a fishy flavour and odour, together with increased acidity. This organism is one of the *Escherichia*, which cannot resist efficient sterilisation. It usually gains entrance to the milk because of inefficient sealing of the cans.

The *chemical and physical* defects which may occur in evaporated milk are:

(1) Curdiness.
(2) Sediment.
(3) Fat Separation.
(4) Brown Coloration.

(1) Curdiness.—When milk exhibiting a low temperature of heat coagulation is sterilised, a hard curd is formed, which cannot be broken up and rendered homogeneous by shaking. The factors concerned in this formation are:

(*a*) Raw milk possessing a high bacterial content and of excessive acidity, or milk which contains organisms of the *Streptococcus liquefaciens* type, which produce a clotting enzyme, is conducive to curdiness. These organisms may multiply rapidly if a long interval is allowed to elapse between condensation and sterilisation.

(*b*) Milk containing an excessive albumin content, e.g., colostrum, favours heat coagulation.

(*c*) If the balance of mineral salts in the milk is faulty, this defect may occur. It is usual to rectify the salt balance before treatment takes place. Forewarming at a temperature of 203° F. will stabilise the salt balance, as the albumin is coagulated and part of the calcium precipitated.

(*d*) Milk in which the total solids are highly concentrated will curdle more easily than will milk possessing a low concentration. Milk produced to the British standard requires to be carefully handled.

(2) Sediment.—A gritty sediment is commonly deposited at the base of the cans during storage. This deposit is formed during sterilisation and consists of calcium and magnesium salts. Less deposit is formed when the milk is stored at reasonably low temperatures, as these salts are more soluble in cold than in warm milk. Highly concentrated milk deposits more sediment than is the case with products of low concentration, this being due to the greater concentration of the mineral salts. Differences in the quantity of sediment deposited are due to fluctuations in the mineral content and salt balance.

(3) Fat Separation.—It is not usual for the fat to separate and rise to the top of the cans, because of the high viscosity of the product. This, however, sometimes occurs when the milk has not been homogenised. When the can is shaken, the fat is churned into masses. This defect occurs in milk which contains large fat globules. Homogenisation is the surest method of preventing this separation.

(4) **Brown Colour.**—An objectionable brown colour is sometimes found in cans of evaporated milk. The principal factors in its prevention are the temperature at which the milk is forewarmed and the addition of sodium bicarbonate. The sterilising temperature should always be as low as possible, consistent with germicidal efficiency. Less difficulty is experienced with high temperatures for short periods than with the application of a lower temperature for a longer period. The addition of sodium bicarbonate prior to sterilisation acts as a stabiliser, but is detrimental to the colour. It is therefore more advisable to add either sodium phosphate or citrate. It has been found that a forewarming temperature of 203° F., if applied for a short period, will not affect the colour of the milk after sterilisation, but, if the milk is held at this temperature for thirty minutes, the milk will be appreciably affected. Colour production is also reduced when the milk is homogenised prior to sterilisation. This is probably due to the fact that the larger fat globules are broken down during the process.

Bacteriological Examination

Mention has already been made of the bacteriological tests applied to raw milk prior to evaporation (see pages 251 to 253). The following tests should always be carried out:

(1) Bacterial Count.
(2) *Bacillus coli* Estimation.
(3) Methylene-blue Reductase Test.
(4) Resazurin Test.
(5) Fermentation Test.
(6) Acidity Test.
(7) Sediment Test.

As in the case of sweetened condensed milk, no legal standard exists for the bacterial content of the evaporated product. This seems to be a serious omission, as the milk should be sterile if efficiently processed. The following examinations are usually made:

(1) Microscopic Examination of the Sediment.
(2) Bacterial Count.
(3) *Bacillus coli* Estimation.

A description of the methods used in carrying out these tests has already been given in the previous chapter (see pages 253 and 254), the technique in each case being identical.

Chemical Examination

Upon arrival at the factory, the raw milk is subjected to the following routine tests:

(1) Estimation of Butter-fat Content.
(2) Solids-not-fat Content.

The methods used have already been described on page 254.

The method of examination of the finished product is similar to that used in the chemical examination of sweetened condensed milk, as described on pages 255 and 256. The following tests are usually made:

(1) Fat Percentage.
(2) Total Solids Content.
(3) Ash.
(4) Proteins.

Legislative Control

The legislation dealing with the production and sale of evaporated milk is similar to that set out in the previous chapter (see pages 256 to 259). The only difference is to be found in the Schedule of the Public Health (Condensed Milk) Regulations, 1923, dealing with the labelling of evaporated or unsweetened condensed milk. The two paragraphs in the Schedule referring to this type of milk have been repealed by Article 4 of the Amendment Regulations of 1927. The amended portions are set out below:

Public Health (Condensed Milk) Amendment Regulations, 1927

Article 4 (ii).—In the case of full-cream milk (unsweetened):

CONDENSED FULL-CREAM MILK, UNSWEETENED

THIS TIN CONTAINS THE EQUIVALENT OF (a) PINTS OF MILK

(iii) In the case of skimmed milk (unsweetened):

CONDENSED MACHINE-SKIMMED (or CONDENSED SKIMMED) MILK, UNSWEETENED

UNFIT FOR BABIES

THIS TIN CONTAINS THE EQUIVALENT OF (a) PINTS OF MILK

As already mentioned on page 259, in connection with sweetened condensed milk, the words **"UNFIT FOR BABIES"** have now been replaced by the words **"NOT TO BE USED FOR BABIES"** on containers of this type of milk.

The following war-time Regulation deals with this type of milk:

Defence (General) Regulations, 1939—60CAA

This Regulation prohibits, without licence, the sale of full-cream, unsweetened condensed milk with less than 7·8 per cent. milk fat and 25·5 per cent. milk solids including fat (by weight). Condensed milk for export or in tins of over 5 lb. in weight is excepted. The chemical standard of unsweetened condensed milk is reduced by this Order to that legalised in the United States of America from which country large quantities of this type of milk have been imported to this country during the War.

CHAPTER VII

DRIED MILK

Introductory

DRIED milk is produced and sold in this country in large and increasing quantities, principally for use as a basis for the many varieties of infant foods now upon the market although the shortage of liquid milk during the War has been the cause of its widespread use for many other purposes. Liquid milk contains an exceedingly high proportion of water, and is therefore a bulky food to transport, while, in addition, it is extremely perishable. Because of this fact, milk in a dried and powdered condition is extremely useful. The drying process ensures that the milk solids are obtainable as a dehydrated powder which can be stored for long periods and readily reconstituted into normal milk. The resultant product is, therefore, of great benefit to the public and to manufacturers, bakers, and confectioners. Dried milk is also used for the manufacture of emulsified milk, cream, and ice-cream.

The sales of dried milk or milk powder as it is often termed have been steadily increasing during the last few years, although the quantity of milk produced in this country by drying methods is only a small percentage of the raw milk produced annually. Before the War, large amounts were shipped from Holland, but when this source of supply was stopped in 1941, increasing quantities were imported from the Colonies and the United States of America, the latter country being almost entirely responsible for the dried skimmed-milk received here and sold on behalf of the Ministry of Food under the name of "Household Milk."

The preparation of a perfect dried milk would solve to a great extent the difficulties experienced by milk distributors following upon seasonal surpluses and shortages, and many authorities are of opinion that the future of the milk industry will tend towards the drying of milk upon an extensive scale. This may happen at some future date, but at present certain slight defects experienced with powdered milk preclude any possibility of this being carried into immediate effect.

The quantity of powder obtained from raw milk depends to a great extent on the quality of the liquid treated. Full-cream milk on an average produces $1\frac{1}{4}$ to $1\frac{1}{2}$ lb. of powder per gallon, while from separated milk approximately 1 lb. per gallon is obtained.

Composition and Properties

The composition of dried milk depends upon two variable factors, as follows:

(1) The composition of the raw milk used in manufacture.
(2) The effect of the processing upon the removal of the moisture.

There is no general standard governing the composition of dried milk, and, as a result, considerable variations are encountered. The table set out

below was compiled by Hunziker in order to summarise variations in composition found by various investigators.

TABLE 15

COMPOSITION OF MILK POWDERS

Type of Powder	Water	Fat	Lactose	Protein	Ash
Whole-Milk	1·40–6·39	25·00–29·16	31·42–37·88	24·59–32·06	5·63–6·24
Part Skim Milk	2·12–8·30	13·00–21·96	34·67–48·85	25·69–38·39	7·87–8·24
Skim Milk	1·00–7·40	1·00– 2·55	45·60–52·24	33·29–37·70	7·87–8·24
Cream	0·56–0·80	50·40–71·15	14·74–25·45	11·12–19·19	2·43–4·16

The Public Health (Dried Milk) Regulations of 1923, as amended by the Regulations of 1927, fix the following standards:

	Percentage of Fat
Dried Full-cream Milk . . .	26·0
Dried ¾-cream Milk . . .	20·0
Dried ½-cream Milk . . .	14·0
Dried ¼-cream milk . . .	8·0

Containers require to be labelled to show corresponding quantity of milk of grade indicated.

	Per cent.
Dried Skimmed Milk . .	9·0 Solids-not-fat

It will be observed from Table 15 that powdered milks differ chiefly with regard to the percentage of fat contained. They also differ in respect to the physical state in which the fat is present. Some dried whole-milks may have a fat content exceeding 28 per cent., while, in the case of powdered skimmed milk, this may be less than 3 per cent. Some dried milks contain added sugar, while alkali is added to others in order to improve the solubility of the powder.

Considerable variations exist between individual powdered milks as to the ease with and the extent to which they can be reconstituted by the addition of water into a fluid resembling milk. It often happens that the physical and chemical properties of the milk solids are so changed during the processing that subsequent mixing with water will no longer produce a fluid which resembles milk, even in a remote degree. Thus the casein may be coagulated and will not assume a colloidal condition on reconstitution.

The solubility of a sample of any powdered milk may be estimated in the following simple manner. A test-tube is filled with water and a small quantity of the powder to be tested is floated upon the surface. If the powder is readily soluble, white, milky streams will commence to flow downwards and the water will quickly become milky. Powders of poor solubility will not disperse. They either remain floating on the surface, or gradually settle to the bottom of the tube, while the water remains relatively clear. To obtain greater accuracy, recourse should be made to standard chemical methods. If such methods are used, the solubility of roller-dried milk varies between 70 and 80 per cent., whilst the solubility of

spray-dried powder varies between 90 and 100 per cent. The insoluble content of dried milk is increased by storage at high temperatures or by contact with moist air.

Roller-dried powder is rather darker in colour than the spray-dried variety, while brownish tints indicate that the drying temperature has been excessive and has resulted in caramelisation of the milk sugar. Spray-dried powders consist of spherical grains, while the grains of the roller-dried variety are irregular in shape. The fat of spray-dried powders consists of small globules. When reconstituted, this fat is restored to much the same condition as it is found in the original milk. The fat of roller-dried powder is present in the form of large drops, which, when the powder is mixed with water, tend to separate out and float upon the surface in an oily layer. It appears that spraying under pressure affects the fat in a similar manner to the homogenising process, which breaks up the fat globules. The coagulation of roller-dried milk with rennet is irregular and unsatisfactory, whereas, with spray-dried milk, rennet exerts much the same effect as occurs with fresh milk, while, in addition, the peroxidases are not appreciably affected by this method of processing.

The two factors which exert most effect upon the properties of dried milk are:

(1) The Precondensing Process.
(2) The Drying Temperature.

(1) The Precondensing Process.—It was the common practice at one time to dry the fluid milk directly, but now, when the milk is spray-dried, it is usual to precondense it in the ratio of 4 to 1 prior to the drying process. This is not commonly done when the milk is roller-dried. The advantage of precondensing lies in the fact that there is a considerable economy in fuel, while the capacity of the drying plant is increased.

If fluid milk is dried without any preliminary precondensing, the resultant powder is of fine texture and of considerable bulk. The powdered, precondensed milk is more granular and can be packed into much less space. The former product tends to cake on contact with water, thus rendering solution exceedingly slow. Although the final solubility may be quite as high as that of powder manufactured from precondensed milk, this prolonged period is disadvantageous from a commercial aspect. A further advantage to be obtained from precondensing the milk is the fact that the resultant granular powder is much easier to collect.

(2) The Drying Temperature.—During the manufacture of milk powder, it is important that the colloids should not be altered by the processing to which the milk is subjected, in such a way that they become insoluble and incapable of forming a homogeneous emulsion when mixed with water. Precipitation of the calcium and magnesium salts will impair the solubility of the dried milk. Any drying process will bring about a certain degree of coagulation of the albumin and globulin contained in the milk, and, when temperatures in the neighbourhood of 220° F. are employed, these constituents are almost entirely coagulated and rendered insoluble. This is particularly the case with roller-dried milk, since the film of milk is then in direct contact with the heated metal surfaces. When the milk is spray-dried, the solubility of the product is not impaired, provided the air currents are properly regulated. It is important to remember that the

milk particles should not be subjected to further heating after the moisture has been evaporated. Even spray-dried milk, if it has been heated to an excessive temperature, will not possess a high solubility in such cases.

The keeping qualities of dried milk are discussed in detail on pages 300 and 301.

Food Value

Dried milk differs from the condensed or evaporated variety in that it is not generally sold as milk powder, but chiefly in the form of infant or invalid foods, of which it forms the basis. It is, or should be, a sterile product consisting of the solids of fresh milk in powdered form. The entire moisture content is evaporated, which prevents the powder becoming a suitable nidus for the growth of micro-organisms. It may be obtained either sweetened or unsweetened and with added vitamins or lactose. The effect of the processing upon its nutritive value should be as harmless as possible, consistent with commercial requirements.

The food value of condensed and evaporated milks has been considered in the two previous chapters, and the statements set out there apply with equal force to the dried or powdered product. There are, however, certain important points to consider, which solely concern dried milk. The lactose present in cow's milk is much less in quantity than is the case in human milk, and for this reason cow's milk is usually "humanised" by the addition of sugar before being fed to infants. Dried milk may have its lactose content artificially increased by adding lactose, either in solution or in the form of whey, to the liquid milk prior to drying. In this manner, any deficiency in the lactose content due to processing may be remedied.

The type of protein insolubility which occurs in dried milk can hardly be compared with the heat denaturation which takes place in the evaporated product. In the manufacture of milk powder, overheating is liable to occur during the roller process. This excess is sometimes large, as the internal surfaces of the rollers occasionally reach a temperature of 320° F. In the later stages of drying, the solids percentage in the partly dried powder is extremely high, and overheating may take place when the mass is in a semi-solid condition.

The question of the quantities of the various mineral constituents present is comparatively simple. It has already been stated that lactose may be added to dried milk in order to "humanise" the product, and in a similar manner, any deficiency in mineral salts may be made good by direct addition of the necessary salts prior to manufacture. On the whole, the mineral salts in milk are well balanced, but there is usually a deficiency of iron and of copper. Such salts might be added to the milk, but the addition of large quantities would cause considerable harm, due to their catalytic action in oxidising the milk-fat.

The effect of heat upon the vitamins has already been discussed in previous chapters, and the fact that only vitamins A and C are likely to be affected by heat or oxidation stressed. It is claimed by the manufacturers of powdered milk that the application of heat is of such short duration that the vitamins are not destroyed.

An interesting test to discover whether or not the food value of dried milk was equal to that of raw milk was carried out upon groups of children in Fulham and Camberwell at the Princess Beatrice Centre and the Augusta

Johnson Social Centre. The ages of the children ranged between four and ten years, sixty children being used for the test. These were divided into three groups, as follows:

Group A.—Received ordinary home diet without supplementary milk ration.

Group B.—Received 1 pint of pasteurised milk daily.

Group C.—Received 1 pint of reconstituted roller-dried milk powder daily. The powder was reconstituted to the standard specific gravity of raw milk.

The test was carried on for four months, the results being summarised in Table 16.

TABLE 16

	Group A Control	Group B. Pasteurised Milk	Group C. Roller-dried Milk Powder
Average Gain in Height	—	0·25 inch	1·20 inch
Average Gain in Weight	2 lb. 9 ozs.	3 lb. 6 ozs.	3 lb. 5·46 ozs.

The milk powder was produced by Messrs. Cow & Gate, Ltd., from English pasteurised milk.

It will be seen that the results obtained from both whole and powdered milk were much superior to those obtained when the children did not receive any supplementary ration. The weights of Groups B and C were approximately the same, but those children receiving reconstituted milk showed a marked increase in height over those receiving whole-milk.

The question of the food value of dried milk is an exceedingly important one, particularly with reference to its suitability as a food for infants and, to a lesser extent, for expectant mothers. As already indicated, experiment appears to show that the dietetic value is at least as high as that of raw, "liquid" milk, to which must be added the vitally important fact that its bacterial content should in every case be negligible. The problem is, however, complicated by the extraordinary extension of the dried-milk industry in connection with Maternity and Child Welfare Centres (for further details see page 319). Thus the problem of the food value is inextricably bound up with the question of distribution, price, added constituents, simplicity of reconstruction, and even the domestic attractiveness of the product. Most authorities are now concentrating upon dried milk in one form or another in preference to the raw product, and find the former article very well suited to their requirements. There is certainly evidence to show that the processed article lacks nothing which the original milk contains, while, in addition, it possesses numerous advantages peculiarly its own.

Uses of Dried Milk

Dried milk is now used for a great variety of purposes, such as the manufacture of infant and invalid foods, bread and biscuit-making, ice-cream manufacture, for animal feeding, in the production of patent flours, and on shipboard and in the tropics. In addition, the possibilities arising out of the storage of milk in this form, particularly on shipboard and in tropical countries, with a view to subsequent reconstruction in its liquid

form, must be remembered. When dried milk was first manufactured, its storage for any lengthy period was difficult, by reason of the tendency of the fat which it contained to become rancid. Because of this, most of the powdered milk was prepared from separated or skimmed milk. Owing to improvements in methods of manufacture, particularly in the method of spray-drying, it is now possible to manufacture dried milk from whole-milk, which can be stored almost indefinitely. This development has played a great part in increasing the uses to which powdered milk may be put.

As previously mentioned, dried milk forms a basis for many infant and invalid foods, which are of innumerable types (for further details, see Chapter VIII). The utilisation of dried milk for animal feeding is increasing. It is usual to dry butter-milk which possesses a high protein content together with the necessary calcium and phosphorus. This type of dried milk is used for feeding poultry and pigs, either separately or in conjunction with other ingredients, and has proved very successful.

Dried milk and dried whey are extensively employed in the baking trade with advantage to all concerned. Such products give the bread with which they are mixed an added nutritional value, while, in addition, they improve the flavour, texture colour, and volume of the loaves. Dried skimmed milk will improve the stability of the dough and increase its absorptive power. It will also assist the fermentation process.

Dried Milk and Disease

No definite outbreaks of disease have been traced to the consumption of dried milk.

Effect of Heat on Milk

The effect of heat on milk has already been dealt with in the two preceding chapters. It is therefore unnecessary to discuss the matter further here, except to add that, in certain cases, very high temperatures are used, the higher the temperature attained, the more likely it being that the milk will be affected, provided such temperatures are applied for any considerable period. Roller-dried milk, on account of the high temperature of the final drying, usually possesses a caramelised flavour. On the other hand, this flavour is usually absent from spray-dried milk, although localised overheating at the base of the drying chamber may induce a slightly cooked flavour.

Manufacturing Methods

The manufacture of dried milk is a long and complicated process which requires detailed consideration. Appert, in 1810, dried milk and made it up into tablet form. In 1855, Grimwade, secured a patent for the first commercial process which was used for a number of years. This was known as the dough-drying system, the milk being evaporated to a dough-like consistency, which was dried and then ground into powder. Open pans were used for evaporation and the dough was dried by pressing it into layers which were passed between hot rollers. This method now possesses only an historical interest, having been superseded by the more up-to-date methods now to be described.

Milk-drying is a process which aims at removing practically the entire moisture content of the milk, by evaporation. The result is a dry powder which includes the total milk solids. The milk is thus reduced in bulk, facilitating storage and transport. The three methods of drying in general use are as follows (see pages 283 to 299 for further details):

(1) ROLLER FILM-DRYING.—This method is popular, the milk being spread in a thin film on revolving, steam-heated rollers. Evaporation takes place and the dried powder is scraped off with knives. The rollers are exposed to the open air. This is the most economical method from the point of view of installation and operation and will probably retain a limited field of usefulness.

(2) VACUUM ROLLER-DRYING.—The principle of this method is similar to that of roller film-drying, except that the rollers are enclosed in a chamber in which a vacuum is maintained. This method is more costly to install and operate than atmospheric drying methods.

(3) SPRAY-DRYING.—This is the most costly of the three methods although it is likely that the future of dried milk lies with this process. The precondensed milk is atomised and is then sprayed into a stream of heated air, which evaporates and carries off the moisture, the milk solids being deposited and collected as a fine powder.

The quality of the final products accruing from these three methods is proportionate to the cost of production in each case.

Perfect milk powder should, when reconstituted with a suitable quantity of water, give a fluid identical in every way with fresh milk. In practice, however, very few powders attain this standard.

The requirements of a good milk powder are:

(1) SOLUBILITY.—A satisfactory spray-dried powder is almost 100 per cent. soluble. Milk powder produced by the open-roller process has usually a maximum solubility of 85 per cent., while vacuum film-dried powder approaches spray-dried powder in solubility. Insolubility is due to the application of excessive heat during the drying process, which heat causes the colloidal constituents of milk to become denatured and inert.

(2) KEEPING QUALITY.—Good roller-dried powder should keep for a period of six to twelve months without any deterioration in the form of rancidity or tallowiness, always provided that the product is properly stored. The defects mentioned are caused through excessive moisture content or oxidation of the milk-fat. Whole-milk powder usually becomes rancid more quickly than does powder produced from skimmed milk, which will keep for twelve months or longer. while roller-dried whole-milk powder possesses better keeping qualities than the spray-dried product, which will not keep satisfactorily for more than three to seven months.

(3) NUTRITIVE VALUE.—The nutritive value of the powders produced by the various methods may be summarised as follows:

(a) Spray-dried skimmed-milk powder for use in bakeries, by confectioners, ice-cream makers, and for stock feeding, powder manufactured by the open-roller process is preferred.

(b) Whole-milk powder, which when reconstituted will give the equivalent of whole-milk and which is to be used for infant feeding and high-class food preparations, is best produced by the roller method.

The roller-dried milk powders will reconstitute very much more easily than spray powders, and as a result of the heat treatment involved, the rennet curds are very much finer than those produced in spray powder and are, in fact, very similar to those produced in breast milk. Roller milk powder will also keep in very much better condition than spray powder, and is freer from bacteriological contamination.

The detailed method of manufacture may be divided into the following stages:

(1) Preliminary Treatment.
(2) Drying Methods:
    (*a*) Film-drying.
    (*b*) Spray-drying.
(3) Preparation for Sale.

(1) **Preliminary Treatment.**—The milk supply is important. It is essential that only clean milk from healthy cows should be used, and that this milk should be in a fresh condition. The churns of milk are opened on arrival at the reception platform, tested for fat and total solids, sediment, flavour, and bacteria, either by means of a plate count or more commonly by means of the reductase or resazurin tests (a detailed description of the methods employed in carrying out these tests is set out on pages 53 to 55 and 252). All milk which does not comply with the standard in force should be rejected, while the remainder is weighed and pumped up to the process room situated upon the upper floor of the factory. Here it is either centrifugalised or filtered to remove undesirable slime content, this operation being followed by cooling to retard bacterial growth. The cleaned, cooled milk is then pumped into tanks and is again tested for fat, acidity, and total solids, after which it is standardised according to the type of powder being manufactured. If skimmed-milk powder is to be made, the milk is separated (see pages 84 to 89). Before being dried, each tank of milk is checked for quality.

(2) **Drying Methods.**—The two methods employed for drying the milk are:
(A) Film-drying.
(B) Spray-drying.

(A) *Film-drying.*—There are three methods of film-drying, each one possessing certain advantages. These are:

    (i) Atmospheric Roller-drying.
With this method, the drying rolls are exposed to the air, and drying takes place at atmospheric pressure.

    (ii) Vacuum Roller-drying.
When this system is employed, the whole unit is enclosed in an air-tight chamber in which a high vacuum is maintained.

    (iii) Band Film-drying.
Milk is dried on a continuous band by hot air in an enclosed chamber either with or without the employment of a vacuum.

    (i) *Atmospheric Roller-drying.*—This process was first carried out in Great Britain in 1855, and is perhaps the most popular. In considering the method, it is necessary to examine the process, having regard to the following three stages:
    (*a*) Preconcentration of the Milk and Feeding of the Rollers.
    (*b*) Methods of Drying.
    (*c*) Removal of the Milk Powder.

    (*a*) *Preconcentration of the Milk and Feeding of the Rollers.*—It is not usual to preconcentrate the milk in vacuo before it is roller-dried, but in some instances this practice is employed to improve the quality of the milk fed to the rollers. The continuous-operating thermo-compression evaporator is often used for this purpose and may be employed with either roller- or spray-drying apparatus. The process possesses certain advantages in that the

resultant powder is granular in texture and packs into considerably less space. The powder is also easy to collect and is quickly soluble.
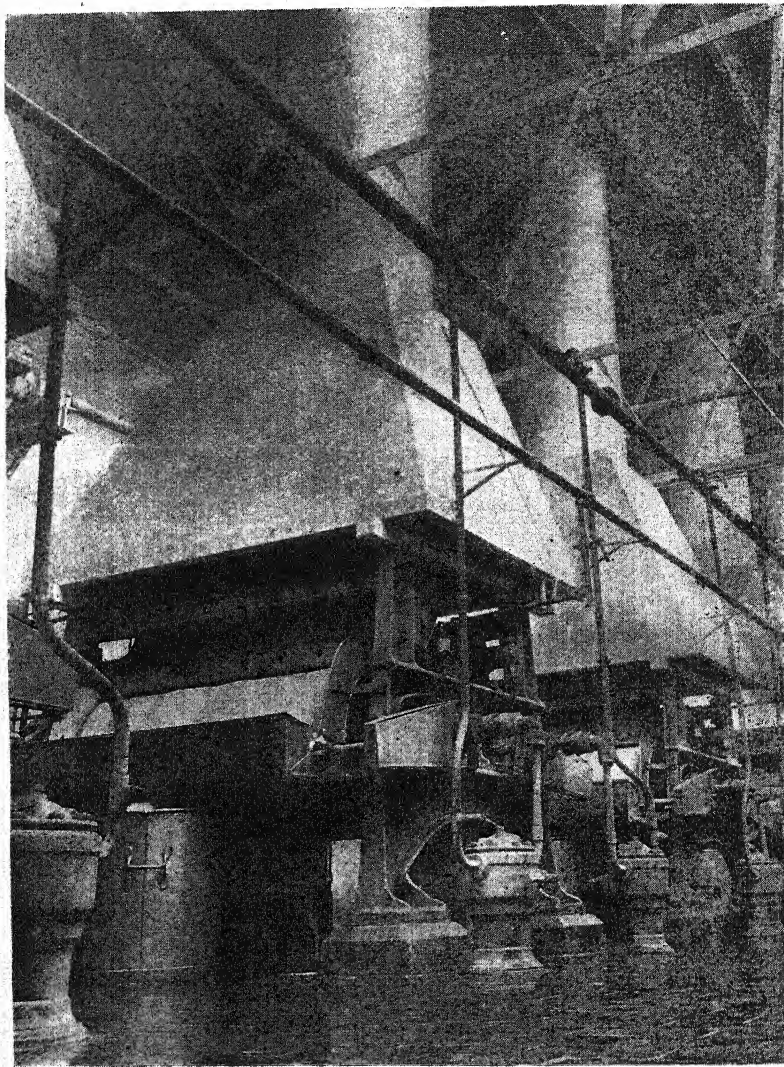
FIG. 69—Modern Roller Driers

Many methods are employed for feeding the milk to the rollers, some method of preheating being usually carried out simultaneously. The simplest method of feeding to a single roll is to arrange the feed in such a manner that the base of the drum is immersed in the milk. If the milk is fed in this way, it requires to be precondensed. If this is not done, it is difficult to obtain a satisfactory film, as the liquid possesses a low viscosity, while ebullition is set up. This latter phenomenon tends to produce lumps of fat upon the surface of the milk, even if precondensation has been employed. The resultant powder varies considerably in quality.

An improvement on this type of feed is the *Kestner* single-drum drier,

in which the feed tray is situated at one side of the drum. The milk is preconcentrated in an evaporator, being fed to the tray at a constant rate. The level of the milk is maintained by an adjustable overflow. The temperature of the milk in the feed-tray is maintained at a low level and there is no violent boiling or irregular preconcentration. The thickness of the film is controlled by the level of the milk in the feed-tray.

Certain Continental types of single-drum driers make use of a separate small roller for carrying the film of milk from the tray to the drum, and in some plants provision is made for cooling the auxiliary roller. The upper part of the roller is usually encased, while a suction fan is provided to draw off the vapours. The powder from the rolls is removed by an endless belt, which carries it away from the drier.

The feed for double-drum driers is arranged in a different manner. The *Hatmaker* method is in common use, but even this type is by no means perfect. The liquid milk is fed into the trough formed between the two rollers, metal end-boards being provided to prevent spillage of the milk from the trough. The pitch of the drum centres is adjusted in such a manner that a thin film of milk is spread upon the rolls. To obtain a uniform film, both drums must be true and wear evenly, and this cannot always be guaranteed. The feed of the *Esscher Wyss* double-drum drier is much more satisfactory. The milk passes to a small vessel, which is situated above a trough. From the trough, the milk flows in a thin film over spreaders, which direct the milk on to the rollers. A casing is provided over the rollers to collect the vapour, which is used to preheat the milk as it passes to the rollers. This enables the milk to be rapidly dried, when an improved product results.

The *Golding* method also makes use of the vapour rising from the rolls, to preheat the milk. The milk is fed into a trough, from which it overflows down evaporating sheets into a lower trough. During its progress, it is heated by the vapours rising from the rollers. The milk passes from the lower trough over a weir, to fall in a thin film on to the drying drums. The temperature of the milk on reaching the rollers is approximately 170° F.

The method of spraying the milk on to the drum has been tried on many occasions, but has not proved satisfactory, as the first liquid which reaches the drum immediately dries, while the later additions form a deposit on this porous layer. This causes the rate of heat transference to be lowered, the capacity of the drums being also affected. This method is used in the *Dew-Drop* drier, manufactured in Germany. Glass-enamelled rollers are used, the preconcentrated milk being fed on to these in very fine drops. Drying is practically instantaneous. The dried particles are removed from the roller by means of brushes.

Whichever method of feed is used, it should comply with the following conditions:

(i) The milk should not come into contact with the rollers until it is in film form and capable of being dried rapidly.

(ii) The milk should, if possible, be preheated by the vapours rising from the rollers, but the milk powder should not come into contact with such vapours.

(b) *Methods of Drying.*—Many methods of drying are in common use, the driers being either of the single- or double-roll type. Single-roll driers of the Kestner type indicated on page 284 are widely used, but the double-drum drier of the Hatmaker type is most commonly employed. This apparatus involves principles common to all types. Although this is one

of the earliest patterns, its design has been little improved. The apparatus consists of two horizontal metal cylinders, closed at the ends by means of steam-tight covers (see Fig. 70). The drums are usually constructed of cast iron, but stainless-steel rolls may be also obtained if desired. Steam at a pressure of 40 to 70 lb. per square inch and at a temperature of 286° to 303° F. is admitted to the interior of each drum by the inlet T_1,
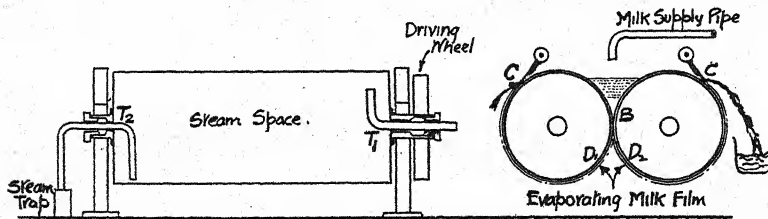
By courtesy of the Hannah Dairy Research Institute.

FIG. 70—Hatmaker Double-drum Drier

the condensate passing out through the outlet T_2 to a steam trap. The outlet pipe is carried down to a point in close proximity to the interior surface of the drum in order to maintain the level of the water in each drum. An air drain is fitted to remove the initial air in the drum, together with that which collects during processing. The drums are rotated by means of a worm gear or chain drive driven by an electric motor, or they may be belt-driven and revolve in opposite directions. The clearance between the rolls is usually in the neighbourhood of 0·02 inch.

When the rolls have made half a revolution, the water is practically all evaporated from the milk, and the residue passes round with the drums to be removed by the scrapers C_1 and C_2. This residue comes away in the form of a thin crinkled sheet and is collected into hoppers placed immediately below the rollers. This material, after removal, is usually placed in a kiln and ground into a powder. The vapours which arise are collected in a hood placed over the rollers and are extracted into the atmosphere by means of a fan or by convection currents.

These machines are massively constructed and require an adequate foundation in order to avoid vibration. The drum speed does not usually exceed sixteen revolutions per minute, since, when this is the case, the scraper knives are liable to "chatter" as the drums revolve. The usual type of knife possesses one long blade, which may be adjusted by means of three sets of screws which give coarse, medium, and fine adjustments and which assist in maintaining uniformity of pressure. Any variation in the pressure is easily noted, since, if the product is not completely removed, it will adhere to the drum and a brown streak will become visible. If this occurs, the adherent material is removed and the blade adjusted at the required point.

The steam pressure in the drums must be maintained at a constant level. When drying operations commence, the drums are started and steam is admitted until they are thoroughly heated. The milk supply is then turned on and drying proceeds as described. At the end of the run, the drums are cleansed with water and thoroughly wiped. A thin layer of vaseline is applied to their surfaces to maintain the polish. This type of plant is simple to operate, reasonably economical to install, while steam consumption is low. Very little power is required to drive the rollers.

As previously mentioned, the milk is not usually precondensed when this method is adopted, as the product boils in the valley formed between the rollers and is preheated and concentrated to a certain degree there. The only advantage to be obtained from precondensing lies in the fact that the bulk of the water is removed at a temperature which is not likely to affect the milk in any detrimental manner. This would cease to be an advantage if highly concentrated milk were fed to the rollers, as the milk is more sensitive to heat when in its concentrated state. Special methods of feeding preconcentrated milk to the rollers have already been described on pages 284 and 285.

The film temperature does not fall below 212° F. The rate of heat transference from the rollers to the milk is lower than that which obtains in vacuum pans. In the early portion of the revolution of the rollers, a layer of air and steam is formed on the metal surface. This is driven off, and, during the latter part of the revolution, the solids are subjected to the full heat of the metal surfaces. In order to prevent excessive heating of the solids, a blast of air is employed in some plants to reduce the temperature of the milk film.

The operation of the rollers during the drying period requires the greatest care, since the delicate constituents of milk are most likely to receive damage during the period the milk is in the form of a film. To prevent this occurring, the drying period must be reduced to a minimum, as the denaturing influence of the heat on the milk is proportional to the period during which the product is exposed to such heat. The film of milk passing to the rollers must therefore be as thin as possible. The time taken for drying usually varies from two and a half to three seconds.

The pressure of steam admitted to drying drums of the Hatmaker apparatus has already been stated, but pressures up to 100 lb. per square inch are sometimes employed, the drum speeds being increased to twenty revolutions per minute in such cases. Superheated steam is occasionally used for this purpose, the quantity of water in the drum being thereby reduced.

The principal objection to the open-roller method of drying is the fact that the milk film is heated to a temperature which seriously impairs the solubility of the final product. This solubility rarely exceeds 85 per cent. The moisture content of the powder as it comes from the rollers should not exceed 2 per cent.

(c) *Removal of the Milk Powder.*—As already indicated, the usual arrangement for removing the film of dried milk from the rollers is a single steel knife fixed to a heavy frame over each roller. The pressure of the knife on each drum is adjusted by screws, springs, or weights, while a coarse, medium, or fine adjustment is provided along the full length of the blade. The blade should be constructed of some material sufficiently durable to withstand the wear to which it is subjected, while, in addition, it should be sufficiently soft to prevent excessive wear upon the drum. Difficulty is sometimes experienced with the single knife, due to the fact that the cutting edge is at a higher temperature than the remainder of the blade. This unequal expansion sometimes renders complete removal of the film at each revolution of the drum impossible, that portion of the film not removed being burnt and thereby spoiled.

The *Kestner* drier makes use of a number of short, independent knives,

which are fixed in such a way that the whole of the drum surface is covered. The knives are held in contact with the drum surface by means of springs and the tension can be adjusted at will. Another method makes use of a blade of thin flexible steel with a double cutting edge, which is reversible. It is claimed that blade friction and cylinder scoring are reduced with this type of cutting surface.

It is essential that the drums should be uniform, otherwise the rollers will be unevenly worn, irrespective of the care with which the blades are fixed. It must also be remembered that the drums and blades are continually wearing and that the metallic dust is likely to become mixed with the milk powder. In this respect, the *Dew-Drop* drier previously mentioned, is useful. This drier is, as already indicated, provided with glass-enamelled rollers, and, as the drying surfaces are composed of glass, the dried drops of milk can be brushed off. There is no likelihood of any metallic contamination of the product occurring when this apparatus is used.

(ii) *Vacuum Roller-drying.*—This is a great improvement on the atmospheric roller method, the milk being dried on rollers enclosed in a chamber in which a vacuum is maintained. The result of this arrangement is to increase the rate of evaporation, while, in addition, drying operations are carried out at much lower temperatures than are required when the open-roller process is employed. The moisture contained in the milk is evaporated at a temperature which depends upon the degree of vacuum maintained in the chamber.

The *Passburg* vacuum drier is one of the most common types in use and was the original of this type of apparatus. Other well-known types are the *Ekenberg* and the *Kestner*. The Passburg drier consists of a single steam-heated drum contained in a cast-iron vacuum chamber, which is fitted with hinged end-covers. Steam is admitted, the condensate being withdrawn in a similar manner to that pertaining to the open-roller process. The bearings of the drum must be rendered airtight by means of packing glands. The drum dips into the milk and picks up a film, which is dried when the roller has made two-thirds of a revolution. To prevent the milk overheating prior to being dried, cooling coils are provided. The powder is scraped off the roller by means of knives, and drops into a truck fixed in a receiving chamber, which is subject to the same vacuum as the drying chamber. The knives are adjusted by means of a hand-wheel fixed outside the vacuum chamber, while inspection lamps and windows are provided. The vapours are drawn off by means of a branch pipe into the open air. When this plant is used, the milk is commonly preconcentrated in an evaporator, which is under the same vacuum as the drying chamber. The concentrated milk is, however, pumped into an open tank before being passed to the drier. The evaporator and drier operate with a vacuum of 28 inches, the milk temperature being in the neighbourhood of 104° F. The steam pressure inside the drum, which revolves at the rate of five revolutions per minute, is approximately 15 lb. per square inch.

This type of apparatus is much more costly than an atmospheric drier of similar size, while, in addition, operating costs are increased. The milk prior to drying is usually concentrated to 40 per cent. of the solids, it being necessary to carry this process as far as possible if operating costs are to be maintained at a low level. The results obtained from the use of the vacuum roller drier are:

(a) The oxidation of the milk by air is reduced and there is a sterile and inert atmosphere in the drying chamber.

(b) By heating at low temperature, the food value is maintained.

(c) The product is easily soluble in water.

(d) The plant is compact and there is little loss of powder.

(e) The conditions of drying and processing can be closely controlled.

Certain obvious disadvantages exist in the operation of this type of plant, which, to a certain degree, counteract the advantages. In the first place, great difficulty is met with in inspecting the product during drying, even though inspection windows are provided. Any defect in the film is thus difficult to correct, owing to the roller being enclosed in the vacuum chamber. In addition, this type of plant is rather inaccessible for cleansing. Sufficient doors could, of course, be provided for this purpose, but the added number of joints tends to cause leakages into the vacuum chamber.

(iii) *Band Film-drying*.—This system is a development of roller-drying, and is a comparatively new idea which is likely to become still more popular. Two methods are used, as follows:

(a) The milk is spread in thin layers on trays, drying being carried out by hot air in an enclosed chamber.

(b) The milk is spread on an endless belt instead of on rollers, and is passed through a hot-air chamber in which a vacuum is usually maintained.

The latter method is most commonly employed for whey-drying.

(B) *Spray-drying*.—Emphasis has already been laid upon the fact that
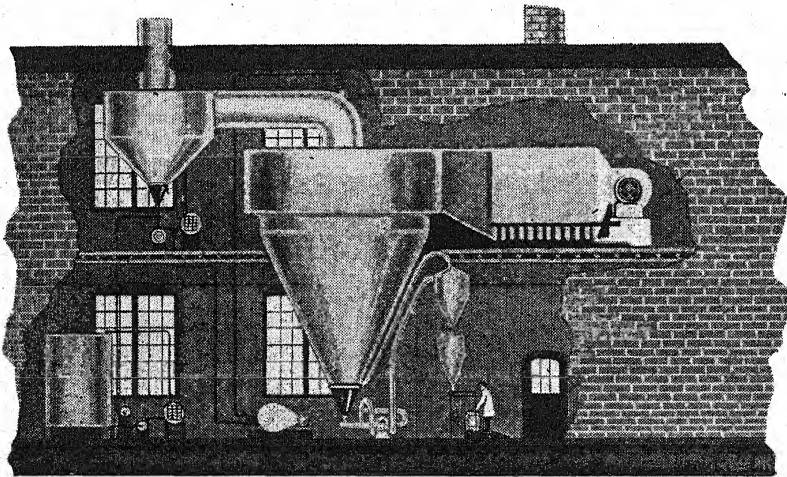
By courtesy of Cow & Gate, Ltd.

FIG. 71—Arrangement of Spray-drying Plant

evaporation should be rapid and that the temperature of the milk should be maintained at as low a level as possible. These requirements may be fulfilled if the spray-drying process is used, while, in addition, a high-quality product can be obtained. The milk, which is usually preconcentrated, is atomised in a current of dry heated air, dehydration being practically instantaneous. In addition to supplying the necessary heat, the hot air carries off the vapours produced in the drying process. The overheating which may occur in open-roller drying is not experienced, as the milk temperature may be kept below 140° F. The milk solids are collected from the drying chamber in the form of a powder.

The plant must be carefully designed in a scientific manner, the process being carried out in the following stages:

(i) Preconcentration.
(ii) Drying Methods.
(iii) Removal of the Powder.

(i) *Preconcentration.*—Upon receipt at the factory, the churns of milk are emptied through a strainer into a tipping tank. In hot weather, the
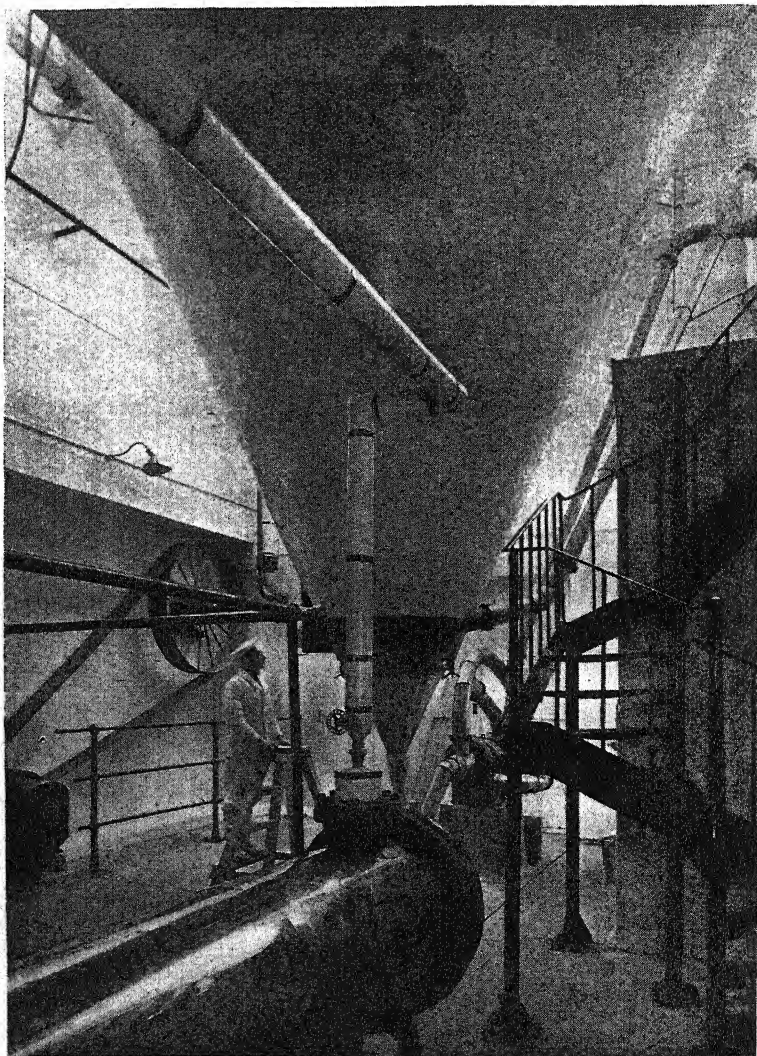
By courtesy of *Cow & Gate, Ltd.*

FIG. 72—Gray-Jensen Spray Drier, showing Preheater in Foreground

milk is cooled and pumped from the tipping tanks into storage tanks, where it is equalised. The milk circulates continuously through the tanks, and passes to a preheater, which raises the temperature to 90° F. If skimmed-milk powder is to be made, the milk is now separated, but if whole-milk powder is desired, the milk passes to centrifugal cleaners, which remove all solid impurities. Samples are frequently taken to ensure a uniform product. The milk, after separation or clarification, is cooled by

means of a tubular brine cooler and passes to large storage tanks, whence it passes in turn to preheaters, where the temperature is raised to 145° F., at which temperature it is held for thirty minutes. It has been found that high-temperature short-time processing at temperatures 190° F. for twenty seconds, has practically no effect upon either the nutritional value or solubility of the spray-dried powder, while advantages from the destruction of bacteria will accrue. Astonishing results as regards keeping quality have followed the use of this high temperature. The powder stored in the presence of air kept about three times as long as when a temperature of 165° F. was used. Laboratory tests showed that the bacterial content of the product after six months' storage was extremely low, while the powder possessed high solubility on reconstitution. The keeping quality was increased from six to nine months to two years. The milk is often homogenised, and is preconcentrated by means of vacuum pans to 40 per cent. solids on a 23-inch vacuum. After leaving the pans, the concentrated milk is sometimes cooled. The liquid passes from either the vacuum pans or the coolers to the drying chamber.

It is advisable for many reasons to preconcentrate the milk prior to drying. The principal reasons for this requirement are:

(1) Economy in the heat requirements of the plant, with consequent economy in fuel.

(2) Increased rapidity in drying.

Theoretically, the greater the quantity of water removed from the milk, the greater the economies which will result, together with a consequent acceleration of the drying process. Practically, however, concentration can be carried too far, as the atomisers are only able to deal with milk of a certain viscosity, particularly if the atomising system is of the pressure-spray or centrifugal type. As previously indicated, the usual preconcentration is 40 per cent. of solids. If any type of atomiser employing steam or compressed air is in use, the milk may be preconcentrated to a greater degree, as the openings through which the milk passes are larger than those used in the first-mentioned systems. There is thus no danger of chokage.

Milk powder produced from precondensed milk is coarser than that produced from fluid milk, while, in addition, it is more easily miscible in water and more readily collected and packed. If the milk has not been preconcentrated it will possess a light, fluffy texture and, on account of its fineness, it is difficult to moisten. Further, a percentage of such powder is drawn away with the exhaust hot air. Preconcentration, in addition, increases the output capacity of the plant.

The preheating of milk has already been described. Following such treatment, the milk is often homogenised, although this is not general when the milk is spray-dried. The merits and demerits of homogenisation have received much consideration of late, conflicting opinions being held by many authorities. On the whole, it would appear that homogenisation of the fluid milk is beneficial for whole-milk powder. The process should always be carried out at pasteurisation temperature, immediately the milk leaves the preheater.

The temperature at which the milk enters the drying chamber varies. In the *Milkal* process, it is in the neighbourhood of 60° F. when sprayed, although, in other methods, much higher temperatures are employed. As an instance, the milk is heated in the *Gray-Jensen* system to 165° F. before

it is atomised. In this latter system, preconcentration is effected by the air leaving the drying chamber, no evaporator being employed.

(ii) *Drying Methods.*—Drying methods vary enormously. Brief descriptions of the principal methods in use are set out below. These are:

(*a*) Merrell-Soule.
(*b*) Krause.
(*c*) Kestner.
(*d*) Rogers.
(*e*) Gray-Jensen.
(*f*) Milkal.
(*g*) Scott.
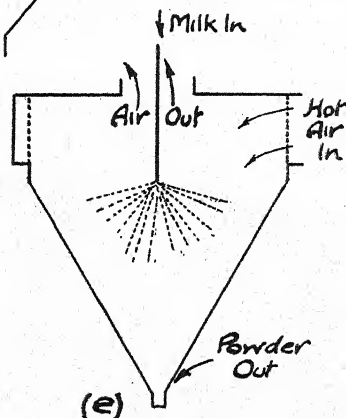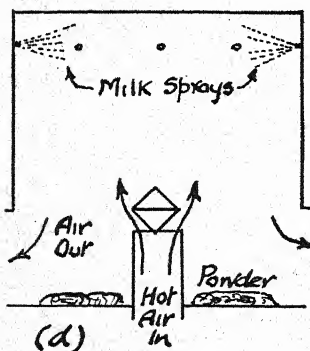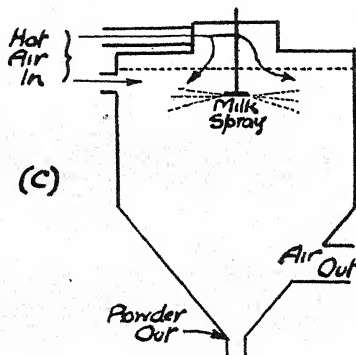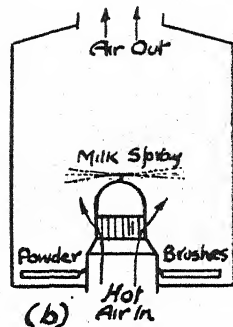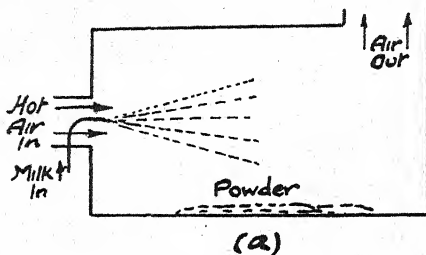
By courtesy of the Hannah Dairy Research Institute.

FIG. 73—Milk Drying Systems

(*a*) Merrell-Soule.   (*b*) Krause.   (*c*) Kestner.   (*d*) Rogers.   (*e*) Gray-Jensen.

(*a*) *Merrell-Soule.*—This is one of the most widely used driers, in which the atomiser works upon the pressure-spray system. The milk is pre-

condensed and forced by a pressure pump through a fine orifice at the side of a rectangular drying chamber. The filtered air is heated in a heating chamber and is pumped through a series of small inlets, which surround

By courtesy of the Kestner Evaporator & Engineering Co., Ltd.
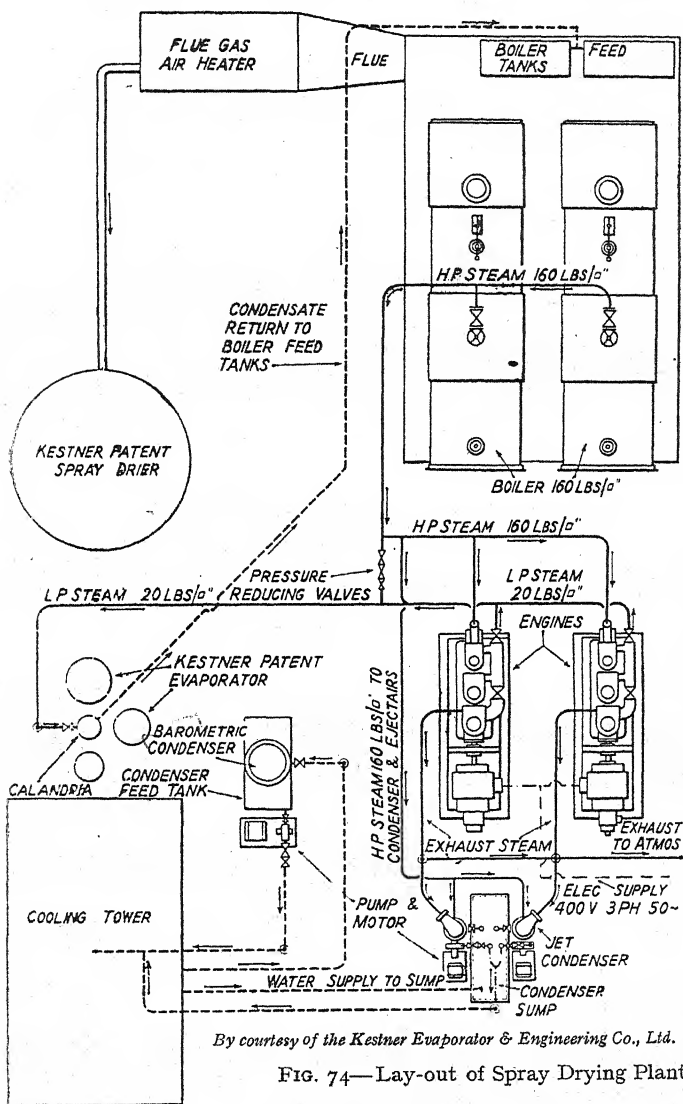
FIG. 74—Lay-out of Spray Drying Plant

the spraying nozzle, into the drying chamber. A swirl is imparted to the air by means of vanes, the air stream travelling horizontally to the opposite end of the chamber, where it passes to the outlet. The used air, which carries along with it fine particles of powder, passes through a dust collector, where the powder which it contains is removed by means of cloth-bag filters. The milk is quickly dried as it leaves the spray, the bulk of the powder falling to the floor of the chamber. Fig. 73 shows a section through the drying chamber. The spraying pressure is between 2,000 and 3,000 lb. per square inch, the temperature of the hot air being approximately 266° F.

(b) *Krause System.*—An outline sketch of the interior of the Krause Drying Chamber is illustrated in Fig. 73. A centrifugal milk spray is used in this process, the liquid being fed on to the centre of a metal disc, which is either flat or saucer-shaped. This disc is revolved at speeds varying between 5,000 and 20,000 revolutions per minute, the milk is atomised in the form of a fine spray and dried in the upward current of air, which enters underneath the milk stream, in the form of a swirl. The air leaves the chamber at the upper end and passes through filter bags which collect the powder allowing the air to pass out. The bags are agitated at intervals and the powder is swept into a suitable receptacle.

(c) *Kestner.*—In this process, milk is fed into a metal cup and flows by capillary force on to the under-surface of a revolving disc, from which it is sprayed downwards into a spiral current of hot air, the temperature of which is 320° F. Fig. 73 shows a section through the drying chamber, while Figs. 74 and 75 show the layout of the plant and the bases of the drying and separating chambers respectively. Part of the hot air enters at a tangent in the upper portion of the drying chamber, in the same direction as the revolving disc. The bulk of the hot air enters at the top centre of the chamber, the two air currents meeting to produce the necessary swirl. A stream of cold air plays on the revolving disc, for the purpose of retarding evaporation at that point. The dried-milk

By courtesy of the Kestner Evaporator & Engineering Co., Ltd.

FIG. 75—Kestner Spray Drier. Showing Base of Drying Chamber, Separating Chamber, and Hot-air Duct (on left).

particles are carried spirally to the bottom of the chamber, while the air also leaves near the base. A preconcentrator may be fitted at the air outlet if desired, in order to utilise the heat remaining in the exhausted air.

(d) *Rogers.*—This apparatus consists of a steam-heated coil for warming the air, a drying chamber, an atomiser, a fan circulating system, and a chamber for the collection of the powder. The air enters the chamber at the bottom centre and is diffused spirally, meeting milk sprayed from each side at the upper end of the chamber. The powder falls on each side of the hot-air inlet being either removed at the end of the day or by a con-

tinuous-removal device. The air outlet is placed near the base of the chamber. Fig. 73 illustrates the usual arrangement. There is no turbulence in the air stream, the atmosphere in the chamber being perfectly tranquil. This renders the existence of a large air chamber necessary, together with low air temperatures. The outlet air is passed through a regenerative heater which is as large as the drying chamber, the spent air being used to preheat the incoming dry air.

(e) *Gray-Jensen.*—The principle of this type of drier is illustrated in Fig. 73. The milk spray is situated in the top centre of the chamber, the incoming liquid being preconcentrated by the heat of the outgoing air, which leaves the drying chamber at a temperature of 160° F. The fluid milk is preheated to approximately 160° to 170° F. before being preconcentrated by the outgoing air from the drying chamber. After preconcentration, the milk is again heated to 165° F. before entering the drying chamber and it now passes to the liquid collector which is an atmospheric evaporator of the continuous type. It consists of a large, cylindrical steel chamber, which is open at its upper end and through which exhaust hot air from the drying chamber is passed. The hot milk is fed into the collector through a pipe near the base, passes up the centre and on reaching the top divides into two horizontal side tubes. These tubes are perforated, milk being sprayed into the collector, the side tubes rotating round the central tube. The collecting tank holds approximately 250 gallons of milk and concentration to 25 per cent. solid is obtained by this method. The drying chamber is shaped like an inverted cone, constructed of stainless steel and is often 40 feet in height by 25 feet in diameter at the top. The hot-air inlet and the exhaust-air outlet are both situated at the upper end of the drying chamber. The hot air, at a temperature of approximately 260° F., enters at a tangent, while the milk spray is situated in the cyclonic current thus set up. Evaporation takes place as the falling hot milk meets the upward blast of hot air. The powder settles to the bottom of the chamber.
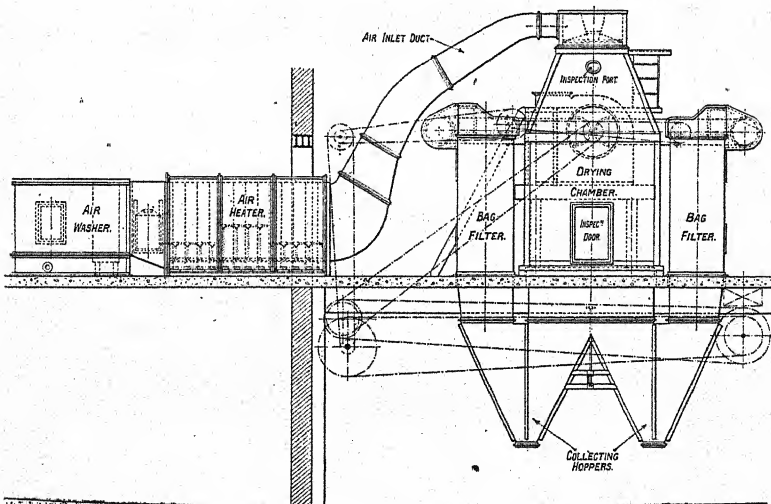
By courtesy of the Hannah Dairy Research Institute.

FIG. 76—The "Milkal" Drying Process

This system possesses three advantages:

(*a*) The heat in the drying air is fully utilised.
(*b*) The powder present in the used air is completely recovered.
(*c*) A separate evaporator to preconcentrate the milk is unnecessary.

(*f*) *Milkal.*—Fig. 76 shows a section through the drying chamber used in this process. The chamber is a rectangular box, which is widened out at the lower end to include the bases of the filter-bag chambers through which the used air passes. At the base of the chamber are two conical hoppers in which the powder is collected, the outlets from which are situated in a lower room of the factory. The air, heated by steam, enters at a point midway between the milk sprays. The temperature of the air is low, while the air stream is tranquil. Two atomisers are placed at the upper end of the chamber on either side of the hot-air inlet, atomisation being effected by means of steam or compressed air. The spray falls by gravity through the air stream. The milk particles are mixed evenly with the tranquil air stream, while the product is at all times subject to constant temperature. The bulk of the powder falls into the collecting hoppers at the foot of the drying chamber. That portion of the powder which is carried off by the used air is collected into filter bags placed in the air outlets. These bags may be shaken mechanically, the powder falling back into the main hoppers. The plant can be sterilised by raising the temperature of the hot air. A good-quality powder, 100 per cent. soluble in cold water, is produced by this method. The advantages claimed for the plant are as follows:

(*a*) The milk is precondensed and is exposed neither to air nor to external heating until it has been atomised.

(*b*) High air temperatures are avoided. Low-temperature air in large quantities is used, and the heat present is thoroughly utilised.

(*c*) The powder is collected at a point well distant from the hot walls of the drying chamber.

(*g*) *Scott.*—This apparatus (Fig. 77) may be adapted to various heating media and is available in all metals and alloys. Its operation shows a marked reduction in fuel costs and by its employment spray drying is brought within the reach of the small manu-
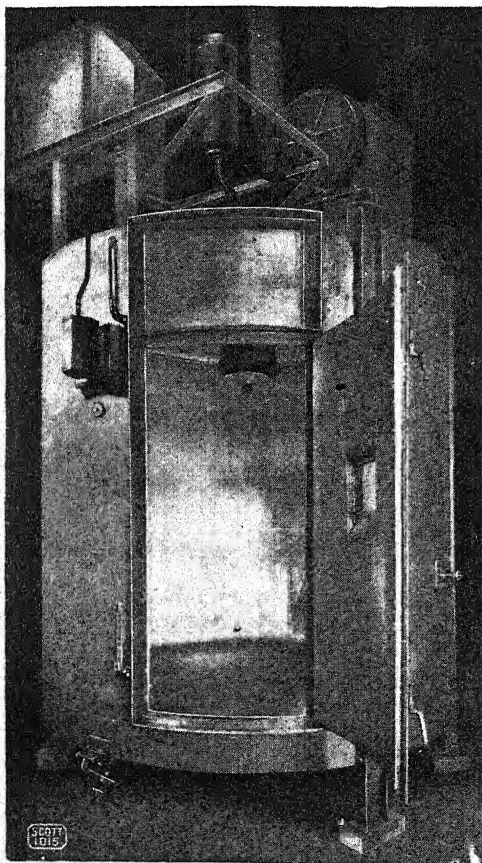
By courtesy of Messrs. G. Scott & Son, Ltd.
FIG. 77—Scott Spray Drier

facturer. One of the novel features of this plant is the streamlined atomiser which tends to eliminate any building up in the atomiser itself and the scoring which results when certain types of atomiser are employed. The atomiser is direct electrically driven by means of a high-speed rotor mounted directly upon the atomiser shaft which eliminates the necessity for the provision of a gear-box. High speeds are obtained by the employment of a frequency changer. If desired a nozzle-type disc atomiser may be fitted. This consists of a number of nozzles mounted on a centrifugal pulley.

When milk is atomised, the following conditions must be observed:

(1) The particles of liquid must be uniform in size.

(2) The direction in which the particles are sprayed must be capable of control.

(3) The atomiser must be capable of working for long periods.

Three main types of atomisers are in present-day use, as follows:

(1) Pressure-spray Atomisers.

(2) Disc Atomisers.

(3) Compressed-air Atomisers.
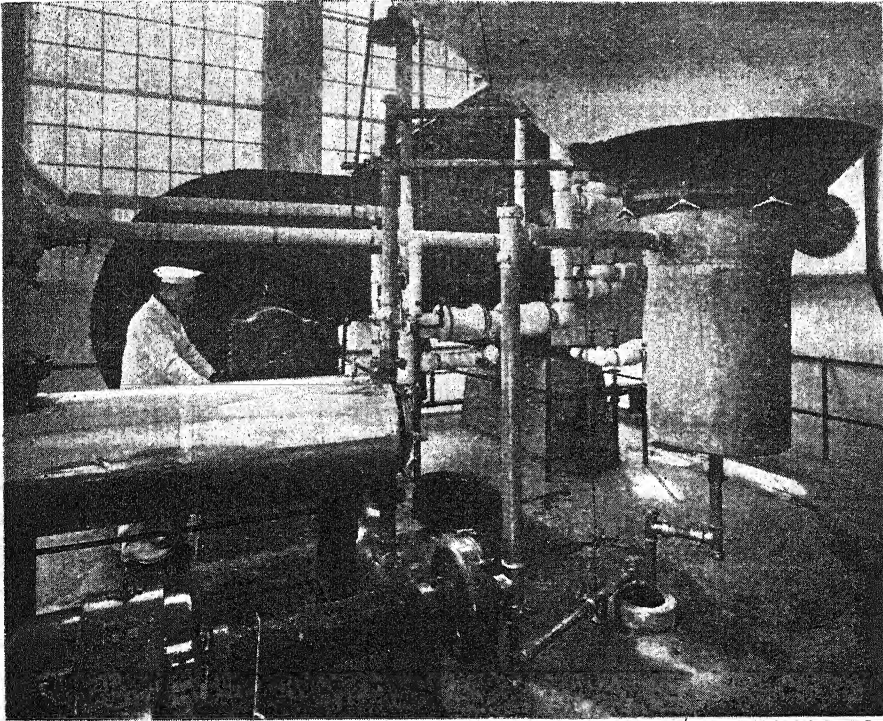
By courtesy of Gow & Gate, Ltd.

FIG. 78—Milk Circulating Chamber, showing Air Heater in Background

(1) *Pressure-spray Atomisers.*—This type of atomiser sprays the milk through very fine apertures at pressures varying from 2,000 to 3,000 lb. per square inch. The aperture or apertures through which the milk is forced by a high-pressure pump are usually some 0·005 inch in diameter. This type of atomiser is employed in the *Merrell-Soule* and *Rogers* systems,

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while, in the *Gray-Jensen* system, a somewhat similar jet is employed, the jet revolving during the spraying process.

(2) *Disc Atomiser.*—With this type, the milk is atomised by a horizontal saucer-shaped disc, which rotates at speeds of from 5,000 to 20,000 revolutions per minute. The milk is fed on to the disc by gravity. The centrifugal force developed causes the milk to travel rapidly to the edges of the disc, whence it is projected in the form of a fine mist. The methods used to feed the disc vary. In the *Krause* system, the atomiser is driven from the underside by a motor, the milk being fed by gravity on to the hollow centre of the disc. The milk is discharged through minute apertures in the hollow disc. In the *Kestner* system, the milk flows by gravity to a cup, whence it flows through openings to the underside of a bell-shaped spraying cup. The milk is spread evenly round the edges of the disc and leaves the edge in a film of regular thickness. Disc atomisers possess many advantages. There is little risk of chokage, while, in addition, the discs are easily cleaned. The size of the particles may be controlled by the speed of the atomiser and highly concentrated milk may be adequately dealt with. This type of atomiser may be run at high speeds for long periods.

(3) *Compressed-Air Atomisers.*—In this type, the milk, as it issues from a small vertical tube, is met by a high-velocity jet of air or steam, which issues from a nozzle situated near the upper portion of the milk jet. The compressed air or steam impinges upon the milk issuing from the jet. A fine mist is formed, which is quickly dehydrated.

Various methods may be used for heating the air employed for drying purposes. These are:

(1) *Steam.*—This is exceedingly convenient if temperatures up to 270° F. are required. The air is passed through tubes surrounded by the heating agent, which may either be high-pressure or super-heated steam.

(2) *Oil Circulation.*—For temperatures above 270° F., the air is heated by passing hot oil through the coils of the heater. The oil is heated in a small stove and is forced through the coils by means of a pump. Very high temperatures may be attained.

(3) *Heating with Flue Gases.*—This method is economical, but large quantities of flue gases at high temperature are required. The air to be heated passes through tubes, which are placed in the boiler flue. The efficiency of the heating surfaces is reduced by deposits of soot.

(4) *Directly-fired Heaters.*—The air is passed through tubes placed inside a furnace. A steady air temperature is difficult to maintain and the tubes soon deteriorate.

(5) *Electrical Heating.*—Unless electrical power is exceedingly cheap, this method is impracticable because of the high cost which it entails. In addition, all conducting shafts require to be insulated to prevent any heat losses.

The purity of the air supplied to the driers is essential, and for this reason, it must be washed. The usual methods adopted involve either washing the air as it passes through the suction pipe by means of water sprays fixed in a special chamber through which the air is required to pass; or drawing the air through vertical gauze screens down which water is running. The air must be filtered through absorbent cotton before it is heated. If this is not carried out, the air will contain excessive moisture.

(iii) *Removal of the Powder.*—After the milk has been dried, the powder is removed by methods which vary according to the system in use. In the *Merrell-Soule* system, 80 per cent. of the powder falls on to the floor of the drying chamber, from which it is removed by rakes, when the drying of each batch of milk has been completed. A similar method of powder

removal is used in the Rogers system. With the *Krause* method, brushes are used to sweep the powder on to a conveyor as it falls to the floor. In the *Gray-Jensen* drier, the powder is collected into a hopper and removed from this by means of a suction blower. The extracted powder is cooled by refrigeration. In the *Kestner* and *Milkal* systems, settling chambers in the form of hoppers are provided, the outlets of which are situated on a lower floor.

A certain quantity of powder particles is carried forward by the used air as it leaves the drying chamber. This powder must be recovered as, in many cases, it may represent 20 per cent. of the whole. Various methods are used for this purpose, the commonest of which employ cotton or linen bags. The exhaust air is drawn through the bags, the powder particles being collected by the fabric, to be removed later. Some mechanical means of shaking the bags must be provided since, if this is not done, the pores of the fabric will become choked, with a consequent increase of pressure in the drying chamber. In some systems, a primitive method of shaking the bags is used, these being beaten at regular intervals by an employee using a pole. The principal disadvantages of filter bags are:

(*a*) The bags must be kept perfectly clean and sterile.

(*b*) Variations in pressure in the drying chamber may occur through choking of the material from which the bags are made.

The *Gray-Jensen* method of powder recovery has already received brief mention. In this system, the fluid milk prior to entering the drying chamber is used to wash the powder particles out of the exhaust air. These particles are carried forward with the ingoing milk, this process being continued until drying operations have been completed. Several other complicated systems of baffles have been devised to assist in recovering powder particles from the used air. One method of precipitation has also been introduced, but in spite of this, filter bags are still the most popular device.

(3) **Preparation for Sale.**—Before the milk powder can be sold, it must undergo the following additional processes:

(*a*) Sifting.

(*b*) Blending.

(*c*) Weighing.

(*d*) Packing.

(*a*) *Sifting.*—When the powder has been removed, it is allowed to cool and is then transferred to storage bins in the sifting room. Here it is screened through fine gauze cylinders (ten to fifteen meshes to the inch), in which a spiral brush revolves. This process removes small quantities of insoluble powder and standardises the texture. After it leaves the gauze cylinders, the powder drops into containers, in which it is removed to the blending room.

(*b*) *Blending.*—The powder, after sifting, is examined for flavour, fat, moisture, bacteria, and solubility, after which it is blended to the required standard.

(*c*) *Weighing.*—The blended powder is passed into hoppers, from which it is fed to weighing machines. These are usually of the automatic type and deliver the powder into bags untouched by hand.

(d) *Packing*.—The weighed powder is transferred to cans or cartons, which are transported by conveyor to the wrapping room. Here the containers are wrapped by machinery in order to ensure complete freedom from contact with air, thus preserving the keeping qualities of the powder. Bulk consignments of powder are usually packed into barrels or metal-lined boxes.

In order to prolong the *keeping quality* of the powder both inert gas packing or vacuum packing may be employed. When inert gas is used, the cans are exhausted and refilled with an inert gas such as nitrogen and then sealed at atmospheric pressure. When vacuum packing is employed the cans are sealed while under reduced pressure. Whichever method is employed the use of a really high vacuum is essential. Compression of milk powder into blocks has been employed and has been found to be a practical proposition. The only difficulty experienced has been the necessity for regrinding the powder, but a machine has been evolved which will overcome this difficulty. The addition of anti-oxidants has also been tried with satisfactory results. The extension of the keeping quality has been extremely useful during the War, when milk powder has required to be stored for long periods.

Gas-packing, which is the most popular method, is carried out in the following manner. The powder is sealed into gas-tight cans which are closed with a lever lid which is finally sealed by soldering a flat metal plate over the whole opening. Two small holes are pierced through the metal of each can and these are placed in a gas-tight cabinet. This is closed and air is evacuated, after which it is filled with nitrogen up to 2 lb. per square inch pressure. The cans are removed and the holes immediately soldered. All parts of the apparatus must be completely gas-tight, while a minimum of free air space must be allowed in the cabinet when filled with cans. The nitrogen supply must be of maximum purity and should be sampled at frequent intervals.

Keeping Quality of Dried Milk

Several factors affect the keeping quality of dried milk in an adverse manner by causing decreased solubility, rancidity, tallowiness, stale flavours, or offensive odours and, in some cases, the development of a brown coloration.

If powdered milk is properly produced and is kept free from contamination, it should contain very few *bacteria*, which also, by virtue of the low moisture content, will rapidly decrease in number during storage. The keeping quality of dried milk is not directly affected by bacteria, although these may cause acidity in the milk prior to drying, and so affect the keeping qualities. If the powder contains an excessive moisture content, bacteria may multiply and eventually cause decomposition.

Spray-dried milk usually contains less *moisture* than the roller-dried product, and this plays an important part in deterioration during storage. It has been shown that with high moisture (over 5 per cent.) there is a greater tendency for milk powder to develop staleness and offensive odours, while the solubility is also decreased.

Tallowiness sometimes develops, due to the oxidation of the fat. This is influenced by several factors, principal among which are the fat and moisture content, presence of metal catalysts, and atmospheric conditions

during storage. It has been found that a high fat content accelerates the development of tallowiness, the opposite being the case with the spray-dried product. During atmospheric roller-drying, the milk is subjected to high temperatures, and it is possible that this causes the fat globules to coalesce. This is not the case with spray-dried powders. Irrespective of the type of powder, tallowiness appears earlier in samples possessing a low moisture content. There is, however, an optimum moisture content for the prevention of tallowiness. The optimum for spray-dried milk is 3 per cent., and for the roller-dried variety, 2 per cent. The presence of metal catalysts, such as copper or iron, which may obtain entrance to the milk from the various utensils or plant with which the milk comes into contact, will accelerate the oxidation of fats and cause tallowiness and rancidity. The atmospheric conditions under which the powder is stored will also influence the development of this defect, the presence of oxygen being virtually essential to the oxidation process. High temperatures hasten the development of stale flavours and offensive odours, and cause loss of solubility.

Rancidity develops in dried milk in accordance with the method of heat treatment used, and depends upon whether or not the lipase is destroyed. If high temperatures are used, this element is absent, and spray-dried milk is therefore most likely to suffer from this type of deterioration. The type of container will also affect the keeping quality. Containers should be capable of being efficiently sealed, in order to prevent the ingress of air and moisture. In some cases, sugar is added to the powder. This provides a protective coating to the milk particles, and is a useful means of preventing defects. It also assists in improving the keeping qualities of the product. Methods to improve the keeping quality of dried milk are briefly outlined on page 300. Of these, gas-packing employed for milk powder made from milk preheated to 190° F. for twenty seconds, seems to be the method most widely practised.

Bacteria in Dried Milk

Because of the temperatures attained in its preparation, together with the germicidal effect resulting from desiccation, dried milk should contain very few bacteria, provided always that pure milk possessing a low bacterial content has been used in its preparation, and that the dried product has been adequately protected from contamination after manufacture. If high temperatures are used in processing, the bacterial content will be low, while the solubility of the product will be impaired. For this reason, roller-dried milk powder contains few bacteria, but its solubility is poor compared with spray-dried powder, in which the bacterial content is much higher.

Those bacteria which survive the drying process are chiefly of the spore-bearing type. Lack of proper handling may result in contamination with bacteria, yeasts, and moulds. Dried milk, purchased in containers, is seldom actually sterile, but the product usually contains insufficient moisture to allow the organisms present to multiply to any appreciable extent. If stored in a damp atmosphere, the powdered milk will absorb sufficient moisture to allow moulds to develop. The number of organisms present in dried milk which is suitably stored tends to decrease considerably during storage.

The types of organisms discovered by various investigators in milk reconstituted from milk powder produced by the roller process are:

(1) *Bacillus mesentericus vulgatus.*
(2) *Bacillus mesentericus ruber.*
(3) *Bacillus cloacæ.*
(4) *Bacillus mycoides.*
(5) *Bacillus subtilis.*

There can be little doubt that high bacterial counts in dried milk are due to contamination after production, and should be taken as an index of such. As regards pathogenic organisms in roller-dried milk, Delepiné has shown that this process may fail to destroy tubercle bacilli present in the milk, although the virulence of such organisms will be decreased. *Hæmolytic streptococci* and *Bacillus dysenteriæ* inoculated into liquid milk subsequently dried by the roller process were destroyed by the processing.

The organisms which survive roller-drying will almost certainly survive the spray-drying process. In addition, staphylococci, sarcinæ, and yeasts have been found in large numbers, while streptococci, spore-bearing and non-spore-bearing bacilli, and moulds have also been isolated from such milks. *Bacillus coli* have been found in samples of spray-dried milk. As the *Mycobacterium tuberculosis* may survive the high temperatures attained in the roller process, it is almost certain that this organism will survive the lower temperatures used in spray-drying.

From a public health viewpoint, the importance of the bacterial content of dried milks lies in the fact that pathogenic organisms are in most instances few, indeed relatively uncommon. This should always be the case with a dried powder manufactured under suitable conditions and from an originally pure milk supply. For this reason, any deviation from the normal standard must be viewed with grave suspicion.

Bacteriological Control

While it is sometimes necessary to estimate the total bacterial content of samples of dried milk, the sample is not usually submitted to any special examinations other than the plate count, while, in addition, it may be examined for acidity and sediment. The methods of sampling demanded for bacteriological purposes require special attention. Particularly is this the case when the effect of moisture on bacterial growth is considered. Because of the facility with which dried milk absorbs moisture, it is important that all utensils and containers used for sampling should be clean and dry, while the sample should be obtained as quickly as possible. If it is necessary to prepare a composite sample in order that the final sample shall be representative of a given quantity of powder, several large portions should be placed in a dry container and thoroughly mixed. This container should be sufficiently large to hold all the material sampled. For a complete bacteriological and chemical analysis, 1 lb. of powder should be obtained.

As previously indicated, the following examinations are usually carried out:

(1) Total Bacterial Count.
(2) Acidity Test.
(3) Sediment Test.

(1) *Total Bacterial Count.*—When the total bacterial count of a sample is to be estimated, 10 grams of well-mixed powder should be completely dissolved in 100 mls. of sterile Ringer solution at 50° C. The 10 grams of powder are weighed into a 6-oz. sterile bottle, which contains 100 mls. of warm, sterile Ringer solution. The bottle should be provided with a sterile rubber stopper. The mixture should be thoroughly shaken to ensure that the powder is completely dissolved. After reconstitution has been completed, the subsequent procedure should be carried out in a similar manner to that described for the making of a plate count in the case of fresh milk (see page 252). The plates should be incubated at both 30° C. and 37° C. in order that a clear picture of the bacterial population may be obtained, as many organisms present may not develop at 37° C. The final count should always be expressed as "number of colonies per gram of milk powder."

(2) *Acidity Test.*—The acidity is calculated on the basis of the reconstituted milk from a 1 in 8 dilution of powder. 2·5 grams of the powder are weighed into a small beaker, a few drops of hot distilled water added, and the powder stirred into a paste. More hot distilled water is gradually added until a volume of 20 mls. is reached. The mixture is then titrated with M/10 caustic soda, using phenolphthalein as indicator, until a faint shade of pink is reached. The number of millilitres multiplied by five gives the acidity in degrees, this being the number of millilitres of caustic soda required by 100 mls. of reconstituted milk.

(3) *Sediment Test.*—One pint of reconstituted milk, produced by dissolving 10 grams of milk powder in 100 mls. of water, is passed through a small circular filter pad of cotton-wool. This pad is then examined for foreign sediment or burnt particles.

Chemical Control

Samples for chemical examination are collected in the manner already described (see page 302). When the sample reaches the laboratory, it is thoroughly mixed to obtain uniformity. The following examinations are carried out:

(1) Fat Percentage.
(2) Total Solids.
(3) Sediment.
(4) Moisture.
(5) Protein.

(1) **Fat Percentage.**—One gram of the powder is accurately weighed and transferred to a hard glass boiling tube (8 in. × 1 in.). Eight millilitres of water are added, followed by two drops of concentrated ammonia solution, and the mixture is boiled until all the lumps disappear. Ten millilitres of concentrated hydrochloric acid are then added, and the liquid is boiled for three minutes and finally cooled. Ten millilitres of methylated spirit are added, well mixed, followed by 25 mls. of ether. The tube is closed with a wet stopper and shaken vigorously for fifteen seconds. It is then allowed to settle and, finally, 25 mls. of petroleum ether are added, a further vigorous shaking for thirty seconds being given. When the layers have separated, the combined fat and ether extract is siphoned off into a flask and the extraction process is twice repeated. The combined extracts are distilled off and the fat residue dried to a constant weight at 102° to 103° C. When

the weight is constant, the residue is repeatedly washed with petroleum ether, any sediment being allowed to settle before each decantation. The flask is dried again at 102° to 103° C. and re-weighed to obtain the weight of fat in the sample used.

(2) **Total Solids.**—0·3 gram of the sample is weighed directly into a dish and 2 mls. of hot water are added. The sample is spread in an even film over the base of the dish. The procedure is then similar to that already described on page 255. The total solids present may also be obtained by subtracting the moisture content from 100 per cent.

(3) **Sediment.**—Twenty grams of dried milk are added to 200 mls. of distilled water at a temperature of 60° F. The mixture is agitated vigorously for thirty seconds by means of an electric mixer, after which it is allowed to stand for five minutes. Any foam then remaining is removed from the surface. The milk is agitated thoroughly by means of a spoon for five minutes, and is thereafter poured into a 50-ml. calibrated conical tube. These tubes are graduated in one-tenth divisions from zero to 1 ml., in two-tenth divisions from 1 ml. to 3 mls., and in five-tenth divisions from 3 mls. to 15 mls. They are also marked at the 50-ml. point.

Conical tubes containing the samples are placed in a centrifuge for fifteen minutes. The supernatant liquid is then siphoned off to the 7-ml. mark, or to within 2 mls. of the surface of the sediment, whichever is possible. Twenty-five millilitres of distilled water at a temperature of 60° F. are then added to each tube. The tubes are thoroughly shaken in order to dislodge any sediment from the lower portions of the tube. The tubes are each filled up to the 50-ml. mark with distilled water at 60° F. and again shaken to mix the contents. They are finally centrifuged for a further fifteen minutes. The quantity of sediment present in each tube can be read off from the graduations, the results being recorded in millilitres.

The quantity of sediment remaining in the tube gives an indication as to the *solubility* of the powder tested.

(4) **Moisture.**—A portion of the powdered milk is ground in a mortar and thoroughly mixed. One gram of the ground sample is placed in a dish and weighed. The contents are then dried in a water bath, until a constant weight is obtained. The loss in weight represents the moisture, which is calculated to a percentage.

(5) **Protein.**—The protein content of dried milk is estimated by Kjeldahl's method, described on page 57. This gives the nitrogen content, which is multiplied by 6·38.

Legislative Control

The legislation governing the production of dried milk is similar to that set out on page 257. In addition to the legislation there summarised, certain special Regulations are in force, the text of which is reproduced below:

Public Health (Dried Milk) Regulations, 1923

Definitions: "Dried Milk" means milk, partly skimmed milk, or skimmed milk which has been concentrated to the form of powder or solid by the removal of water.

"Label" includes a mark.

It should be noted here that the definitions "Skimmed Milk" and "Gross Weight" possess a similar meaning to those given in the Public Health (Condensed Milk) Regulations, 1923 and 1927 (see page 257).

These Regulations apply to dried milk to which no other substance has been added, and to the dried milk contained in any powder or solid of which not less than 70 per cent. consists of dried milk.

Duty of Local Authority to enforce Regulations.—Article 3. This Article states that it is the duty of the Local Authority to enforce these Regulations.

Conditions as to Labelling and Percentages of Fat.—Article 4. It is an offence for any person to sell, expose for sale, or deliver to any purchaser dried milk intended for human consumption unless it (1) is contained in a tin or receptacle which is labelled in the manner stated in the Schedule to the Regulations, and (2) contains not less than the following percentages of milk-fat, viz.:

Dried Full-Cream Milk	Not less than 26%
Dried Three-quarter Cream Milk	Not less than 20%
Dried Half-Cream Milk	Not less than 14%
Dried Quarter-Cream Milk	Not less than 8%

provided that these provisions will not apply where the dried milk is contained in a tin or receptacle whose gross weight exceeds 10 lb., and where dried milk is sold by weight and not placed in a tin in which it is delivered to the purchaser until immediately before such delivery, the provisions of 1 to 4 of the Schedule shall be complied with if the matter required to appear on the label is printed on a separate label or notice delivered to the purchaser, and the declaration required by rule 1 of the Schedule may be varied to relate to 1 lb. or any other weight of article sold.

The remaining provisions are similar to those contained in the Public Health (Condensed Milk) Regulations, 1923 (see pages 257 and 258), with the exception of the Schedule which follows.

SCHEDULE

(1) (i) This paragraph has now been amended by the Amendment Regulations of 1927.

(ii) The label on any tin or other receptacle containing dried milk to which sugar or some other substance has been added shall be in the appropriate form prescribed in subdivision (i) hereof, with the following modifications:

(1) There shall be added to the heading the word "sweetened" if the only substance added to the milk is sugar; the word "modified" if the only substance added is a constituent of milk, and the word "compounded" in every other case; and

(2) The words "with (C) added" shall be added to the last sentence in each case, words being inserted at (C) to specify the substance or substances added.

(iii) The declaration shall be completed as follows:

(1) There shall be inserted at (*a*) the appropriate number in words and figures, e.g. "one-and-a-half (1½)," any fraction being expressed as eighths, quarters, or a half.

(2) There shall be inserted at (*b*) the word "Three-quarter" if the percentage of milk-fat is not less than 20; "Half" if such percentage is less than 20 but not less than 14; and "Quarter" if such percentage is less than 14 but not less than 8.

(iv) For the purpose of this Rule the terms "Milk." "Three-quarter Cream Milk," "Half-cream Milk," and "Quarter-cream Milk" mean milk containing not less than the following percentages of milk-fat and milk solids; that is to say:

	Milk-fat	Milk Solids (including Fat)
Milk	3·6	12·4
Three-quarter Cream Milk	2·7	11·6
Half-cream Milk	1·8	10·8
Quarter-cream Milk	0·9	9·9

and "Skimmed milk" means milk which contains not less than 9 per cent. of milk solids other than fat.

(2) This Rule has now been amended by the Amendment Regulations of 1927.

(3) The label shall, in addition, bear the name and address of the manufacturer of the dried milk or of the dealer or merchant in the United Kingdom for whom it is manufactured.

(4) The label shall be securely affixed to the tin or other receptacle so as to be clearly visible. If there is attached to the tin or other receptacle a label bearing the name, trade-mark, or design representing the brand of the dried milk, the prescribed declaration shall be printed as part of such label.

(5) There shall not be placed on any tin or other receptacle containing dried milk—

(a) Any comment on, explanation of, or reference to either the statement of equivalence contained in the prescribed declaration or the words "partly skimmed," "machine skimmed," "skimmed," or "unfit for babies"; or

(b) Any instructions as to dilution, unless either—

(i) the fluid produced in accordance with such instructions would contain not less milk-fat and not less milk solids than milk, partly skimmed milk, or skimmed milk as defined in Rule 1 of this Schedule, as the case may require; or

(ii) such instructions clearly specify that the fluid so produced is not of equivalent composition to milk, partly skimmed milk, or skimmed milk as the case may be.

(6) Wherever the word "milk" appears on the label of a tin or other receptacle of dried partly skimmed, or skimmed milk as the description or part of the description of the contents, it shall be immediately preceded or followed by the words "partly skimmed," "machine-skimmed," or "skimmed," as the case may require.

In 1927, the Public Health (Dried Milk) Amendment Regulations were put into operation with a view to giving greater prominence to the words "Unfit for Babies." The relevant portions of these Regulations are set out below:

Public Health (Dried Milk) Amendment Regulations, 1927

Labelling.—Article 3. The following provision shall be added to and form part of the principal Regulations immediately after Article 4 thereof, that is to say—

"4a.—Where a tin or other receptacle containing dried skimmed milk is required by Article 4 of these Regulations to be labelled, no person shall expose or offer for sale such a tin or receptacle in a paper or other wrapper unless such wrapper has printed on the outside thereof the words 'unfit for babies,' such words being contained within a surrounding line. The type used for the words shall not be less than quarter of an inch in height and the printing shall otherwise conform with the rules prescribed for the printing of the same matter on the label affixed to the tin or other receptacle."

Article 4.—The following paragraphs shall be substituted for subdivision (i) of paragraph 1 and paragraph 2 of the Schedule to the principal Regulations:

(i) Every tin or other receptacle containing dried milk (other than dried milk to which sugar or some other substance has been added) shall bear a label upon which is printed such one of the following declarations as may be applicable or such other declaration substantially to the like effect as may be allowed by the Minister:

(1) In the case of full-cream milk, that is to say, dried milk containing not less than 26 per cent. of milk-fat:

DRIED FULL-CREAM MILK

THIS TIN CONTAINS THE EQUIVALENT OF (a) PINTS
OF MILK

---

(2) In the case of partly skimmed milk, that is to say, dried milk containing not less than 8 per cent. but less than 26 per cent. of milk-fat:

DRIED PARTLY SKIMMED MILK ((b) CREAM)

**SHOULD NOT BE USED FOR BABIES
EXCEPT UNDER MEDICAL ADVICE**

THIS TIN CONTAINS THE EQUIVALENT OF (a) PINTS
OF (b) CREAM MILK

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(3) In the case of skimmed milk, that is to say, dried milk containing less than 8 per cent. of milk-fat:

DRIED MACHINE-SKIMMED MILK (OR DRIED SKIMMED MILK)

UNFIT FOR BABIES

THIS TIN CONTAINS THE EQUIVALENT OF (a) PINTS
OF SKIMMED MILK

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(2) (a) The prescribed declaration shall be printed in dark block type upon a light-coloured ground.

(b) There shall be a surrounding line enclosing the declaration, and in the case in which the words "unfit for babies" are required to be used there shall be another such line enclosing those words.

(c) The distance between any part of the words "unfit for babies" and the surrounding line enclosing those words shall not be less than one-sixteenth of an inch.

(d) No matter other than that hereinbefore prescribed shall be printed within either surrounding line.

(e) The type used for the declaration shall not in any part be less than one-eighth of an inch in height (or if the gross weight of the tin or other receptacle does not exceed twelve ounces, one-sixteenth of an inch in height) and the type used for the words "unfit for babies" shall not be less than twice the height of any other part of the declaration.

As already mentioned with regard to condensed and evaporated milks, the words "**UNFIT FOR BABIES**" have now been replaced by the words "**NOT TO BE USED FOR BABIES**," as set out in the Ministry of Food Circular, 2830.

The Milk Powder (Licensing and Control) Order, 1940

This war-time Order prohibits the manufacture or sale by manufacturers of milk-powder without licence from the Minister of Food.

SUBSIDIARY MILK PRODUCTS AND USES FOR MILK

AN attempt has been made in the foregoing chapters to discuss in some detail the chief products of milk. In addition to these, however, there are others of lesser repute which are, in certain respects, of almost equal importance. These subsidiary milk products are briefly discussed in the remaining pages of this volume. It will be seen that, not only is milk used in the preparation of products for human consumption, but also as a food for animals, in the preparation of medicinal specialities, and in several commercial directions. Although no attempt has been made to study the significance of these products in an exhaustive manner, it is hoped that the reader may obtain a broad conception of the multitudinous uses to which milk may be placed.

Fermented Milks

The process of fermentation is one of the oldest methods known of preserving or improving the nutritive constituents of milk. While the process is still carried on to some extent in this country to-day, modern methods of food preparation have rendered it largely unnecessary. In spite of this fact, a growing demand for fermented milks has tended to make itself apparent, principally because of the claims put forward as to their exceptional health-giving properties. Most fermented milks are of foreign origin, being largely produced in countries where they were originally looked upon as a natural method of consuming milk. The milk of various animals is used in production, as was the case in this country in the Middle Ages, when ewes were employed in addition to cows for milk-producing purposes.

To preserve milk by fermentation, certain organisms are added, the effect of these organisms being to produce substances which will retard decomposition. In some countries, the organisms essential to this purpose are normally found in the product, but milk may be artificially inoculated with the necessary organisms.

The fact that milk could not be kept fresh was presumably the origin of the custom of drinking soured or fermented milk. Once milk has clotted, the acid which develops prevents any further decomposition. Various authorities have urged that the health of the population would be considerably improved by the consumption of such milks, and Metchnikoff in his book "*The Prolongation of Life*" held out hopes of long life to those who made considerable use of this product. Metchnikoff was impressed by the longevity of milk drinkers in Balkan countries, and he promised a long and healthy life to all consumers of milk soured by the *Bacillus bulgaricus*. He held that the decay of the human body was due to the absorption of toxins resulting from protein decomposition. This statement inaugurated a cult for this type of milk which has never entirely subsided, the aim of consumers of such milks being to reinstate acid-forming organisms in the body, to restrain putrefactive changes, and to prevent the absorption of the toxins produced by protein digestion.

Bacillus bulgaricus, when present in milk at favourable temperatures, will form sufficient acid to prevent the growth of other organisms. This

organism is to be found in the intestines of those who consume large quantities of fermented milk.   Those persons who consume large quantities of lactose have numbers of *Thermobacterium acidophilum*, which is akin to *Bacillus bulgaricus*, present in the intestines.   It is probable, therefore, that consumers of either soured milk or lactose derive benefit from the acid-forming groups of organisms which both contain.   It would consequently appear that the daily consumption of a small quantity of lactose would be as beneficial as the consumption of large quantities of soured milk, besides being certainly more convenient.

Apart from their medicinal properties, fermented milks possess a high food value, similar to fresh milk, except that in some cases the fat may be partially or entirely removed.   They are pleasant, nutritious, and refreshing.   The fat content may be unaltered, the sugar content is only slightly reduced, part being converted into acid, alcohol, or gas, while the casein is precipitated in an easily digestible state.   The increased digestibility is not due to any change in the chemical composition of the milk, but to the fact that the casein is present in a finely divided condition. These milks are frequently used in cases of gastric irritation, when it is difficult to find foods which can be retained by the stomach.   *Kefir* and *Koumiss* are often used under such circumstances, as the stimulating action of the carbon dioxide which they contain is believed to assist in their digestion.   The value of a highly nutritious food which can be digested when other foods cannot will be obvious.

The following are the principal types of fermented milks:

(1) Kefir.
(2) Koumiss.
(3) Yoghurt.
(4) Urda.
(5) Acidophilus Milk.
(6) Leben.
(7) Kaeldermalk.

(1) **Kefir.**—Kefir, or Kephyr, is one of the oldest varieties of fermented milk, the name being derived from the Turkish word "kef," which mean welfare.   It was originally manufactured from the milk of cows, sheep, or goats in the Caucasus mountains and in surrounding districts, but differs from most of the fermented milks produced in Mediterranean countries in that it is elaborated from a dried preparation and contains large quantities of alcohol and gas.   It forms a considerable part of the food of the mountain-dwellers of the Caucasus, who prepare it in leather bottles made from the skin of the goat.   These bottles are hung in a convenient spot where they can be frequently shaken.   In summer, it is usual to hang them in the open air, but in winter they are kept indoors.   Kefir made in this way is slightly effervescent and possesses a pleasant taste, but when made in wooden vessels, as is the practice in some districts, most of the gas escapes.   As the kefir is removed and consumed, fresh milk is added and the process of fermentation continues.

This type of milk is produced by the action of a ferment which has the appearance of yellow grains.   These grains possess an interesting structure.   They consist of a central portion divided into two parts, of which the outer part spreads outwards, forming a convoluted exterior.

These parts are built up, one upon the other, giving the larger grains the appearance of coral. The central portion is composed of a mass of bacterial threads, while in the outer portion, yeasts cells mingled with bacteria are to be found. When these grains are added to the milk to be fermented they swell and rapidly increase in size, forming new grains. When fermentation commences, they settle to the bottom, but, after a short interval, they are carried to the surface by attached gas bubbles. If the fermentation is active, a thick layer of grains will be formed upon the surface of the liquid, although, if well stirred or shaken, the layer will settle to the bottom.

Three types of organisms have been isolated from kefir grains. These are:

(a) *Streptococcus casei.*

(b) *Betabacterium caucasicum.*—This resembles *Bacillus bulgaricus* and forms gas from lactose.

(c) Organisms resembling *Bacillus coli* and *Bacillus cloacæ.*—These ferment lactose and form gas, causing a slimy consistency in the kefir.

(d) *Saccharomyces kefir.*—This is a yeast.

Freudenreich, who investigated kefir grains, states that these organisms are necessary constituents of the grains. *Torulæ* have also been found in kefir, together with lactic-acid organisms. It is quite likely that kefir results from the growth of the different organisms, according to the district in which it is manufactured. The combination of bacteria or of bacteria and yeasts which will produce acid and mild alcoholic fermentations in milk will produce kefir. During its production, the lactose and its products are split up, the lactose diminishing as alcohol and lactic acid increase.

Kefir may be made from whole or skimmed milk. There are four varieties:

(a) *Sweet.*—This takes twenty-four hours to produce and contains little alcohol.

(b) *Medium.*—This takes forty-eight hours to produce and is very effervescent.

(c) *Strong.*—This is produced in three days. It contains a fair quantity of acid and alcohol, and is gaseous.

(d) *Very Strong.*—This is exceedingly acid and alcoholic and contains a large quantity of gas.

The following factors influence its composition:

(a) The milk used.

(b) The ferment added.

(c) The method of preparation.

Typical compositions of the various types of kefir already enumerated are shown in the following table:

TABLE 17

	Percentage			
	Sweet	Medium	Strong	Very Strong
Water	88·2	89·0	89·4	89·0
Lactic Acid	0·8	0·6	0·7	0·9
Alcohol	0·6	0·7	0·8	1·1
Sugar	2·7	2·9	2·3	1·7
Casein	2·9	2·7	2·9	2·5
Albumin	0·3	0·2	0·1	0·1
Fat	3·3	3·1	2·8	3·3
Salts	0·8	0·6	0·7	0·6

The mode of preparation is as follows. The dry grains are softened by soaking in warm water, which is changed several times during the process, when the grains rise to the surface, become white and gelatinous,

and they are then ready for use. One part of prepared grains is added to each three parts of milk, which has been thoroughly heated to destroy any bacteria present. The milk and grains are placed in bottles, which are not stoppered, being covered with cloths or plugged with cotton-wool to prevent contamination. The bottles should be stored at a temperature of approximately 60° F., their contents being frequently stirred or shaken. After remaining in this condition for some ten hours, the milk is strained through cloth and is filled into tightly stoppered bottles, which are kept at the same temperature as previously. The bottles must be shaken every few hours to prevent the formation of clumps of precipitated casein. The product is ready for use at the expiration of twenty-four hours.

The fermentation temperature is important in controlling the relative amounts of alcohol and lactic acid present. At a temperature higher than 60° F., the percentage of alcohol is increased, while, as the temperature is lowered below this point, the quantity of lactic acid increases, while alcoholic fermentation is diminished. Once the process has begun, the kefir grains may be discarded, new kefir being made by adding one part of fermented milk to three parts of fresh milk. The liquid is strained through cloths to remove the grains. After thorough washing, the grains are dried in the sun. They may be stored in this dry condition for several years without losing their vitality.

(2) **Koumiss.**—This fermented milk derives its name from Kouman, an Asiatic tribe. It is very similar to kefir, and is produced by alcoholic fermentation of mare's milk in Siberia, Central Asia, and Southern Russia. Mare's milk, which possesses a high sugar content and is well adapted for alcoholic fermentation, was originally used in its manufacture, and during the summer this milk constituted the entire food of the tribesmen. In Europe, however, where this milk is used mainly for therapeutic purposes, it is produced from cow's skimmed milk, to which milk sugar or whey has been added.

In Asia, no seeds or grains are used in preparing the milk. Fermentation is usually started by adding some fermenting or decaying substance to the mare's milk. Once the process has been started, a small quantity of previously prepared koumiss is added to fresh milk, to continue the fermentation process. Several types of bacteria and yeasts are always present in the milk. Koumiss is a highly effervescent drink, this being due to the fermentation which takes place. The lactic-acid organisms present are allied to *Streptococcus lacticus*, while the yeasts present are also lactose fermenters. Koumiss is less acid and dense, but more alcoholic than kefir. It possesses considerable food value. Its composition varies according to the age, the rapidity of fermentation, and the nature of the causative agents. Typical koumiss produced from cow's milk has the following composition:

	Per cent.
Water	88·8
Lactic Acid	0·8
Alcohol	2·7
Carbon Dioxide	1·0
Milk Sugar	3·2
Casein and Albumin	2·0
Fat	0·8
Salts	0·7

A variety of koumiss known as *Galazine* can be prepared in the following manner. One hundred pounds of separated milk is mixed with 42 lb. of water, 1·75 lb. of granulated sugar, 0·75 lb. of lactose, and 5½ to 6 ozs. of yeast. This mixture is allowed to stand at a temperature of 100° F. for thirty-two hours, being stirred six times at equal intervals. It is then decanted into patent stoppered bottles and stored in a cellar at a temperature of 55° F. It should be used within six days. It is effervescent and has a slightly acid taste. It does not, however, possess the therapeutic properties of any of the other fermented milks.

(3) **Yoghurt.**—Kefir and koumiss are limpid, mildly acid, and distinctly alcoholic. Yoghurt, on the other hand, is a thick, curdled milk which is decidedly acid and contains little or no alcohol. It is known in India, Armenia, the Balkans, and Sardinia under a variety of names, the mode of preparation differing in the various localities mentioned. Goat's milk, cow's milk and even buffalo's milk may be used in its preparation. In Europe, it is usually manufactured from cow's milk. It is a nourishing and refreshing food, which is very easily digested. It is prepared from milk to which cultures of *Diplostreptococcus yoghurt, Streptococcus thermophilus*, and *Bacillus bulgaricus* have been added. The culture is incubated at a suitable temperature until the desired development of bacteria takes place. Milk is curdled within a few hours by *Bacillus bulgaricus* if stored at 107° F., and yields a soft slimy curd. Two per cent. acidity develops in twenty-four hours. After several days, the acidity will have risen to 3 per cent.

In addition to the specific organisms which produce lactic-acid fermentation, there are also some peptonising bacteria present, which produce a partial proteolysis of the casein. This proteolysis is exceedingly important, as it increases the food value of the product. The bacteria develop in large numbers at the commencement of fermentation, but die later as a consequence of the increase in acidity. This milk is prepared in three stages:

(*a*) Preheating, to concentrate and sterilise the milk.

(*b*) Addition of the fermenting agent.

(*c*) Fermentation under thermostatic control.

Preparation is simple. The milk used is preheated at 113° F. following which 2 per cent. of liquid culture is added. The mixture is thoroughly soured and filled into bottles, which are held at a temperature of 113° F. This temperature is maintained until coagulation takes place, usually in three hours' time. The product is then cooled as rapidly as possible, and, when cool, is ready for consumption. The apparatus required for manufacture is inexpensive, being simply a jacketed vessel, heated either by hot water or steam. The liquid culture must be carefully prepared. Three to 5 quarts of milk are maintained at a temperature of 185° F. for thirty minutes, after which they are cooled to 113° F. The dried culture is poured into the milk, which is stirred briskly. The milk is then held at a temperature of 113° F. for some eighteen hours, being stirred several times during the first six hours.

The finished product is different both in appearance and composition from ordinary milk, as it has undergone the following alterations:

(*a*) The water content is reduced by evaporation.

(b) The proteins are slightly peptonised, the greater part of the casein having been curdled by the action of the surrounding acid medium.

(c) The sugar is partially transformed into lactic acid.

(d) The acidity is considerably increased.

The fat and salts remain unaltered. The average composition of Yoghurt is as follows:

	Per cent.
Acidity (Lactic Acid)	0·83
Water	87·30
Fat	3·50
Sugar	3·50
Total solids	2·70

A rapid increase in the lactic acid present occurs during the first few hours after production, due to the activity of the lactic-acid ferments in conjunction with the sugar. The activity of the ferments is checked as the acidity increases, until it finally ceases. In the later stages, a putrefactive process commences which disintegrates the protein substances. Less than two-thirds of the sugar in the milk is fermented, the increasing acidity preventing the acidity of the lactic ferments.

The advantages claimed for the consumption of Yoghurt are:

(a) The bacterial flora of the intestines is beneficially altered.

(b) Constipation, auto-intoxication, and colitis are relieved.

Putrefaction of protein substances in the intestines takes place in an alkaline medium. The presence of lactic-acid-producing bacteria sets up an acid reaction which opposes the development of any putrefactive processes. From the therapeutic point of view, therefore, the acidity is of great importance. Yoghurt should thus be taken medicinally when the acidity is increasing; that is, between the first few hours after production and the following forty-eight hours. Yoghurt may be obtained in tablet form, but the health-giving properties of these tablets is often so greatly impaired as to render them of comparatively little value.

(4) **Urda.**—This is a strongly alcoholic beverage produced in the Carpathians from sheep's milk. It is sometimes known as "sparkling whey." A somewhat similar "whey champagne" known as "*Skuta*" is produced in Chile by the fermentation of whey, with the addition of various saccharine and aromatic substances, chief among which are lactose-splitting yeasts and bacteria.

(5) **Acidophilus Milk.**—This is a cultured offshoot of Yoghurt which was discovered as recently as the year 1900, and this variety of milk exerts a favourable influence upon the bacterial flora of the large intestine, while both constipation and diarrhœa are rapidly and permanently relieved by its use. It is palatable with an agreeably mild, acid flavour and is easily digested. This variety is prepared from milk which has been heated for one hour at 203° F., cooled to 104° F., and finally, after bottling, inoculated with a pure culture of *Thermobacterium acidophilum*. About 1 per cent. of the culture is added to each bottle, which is immediately stoppered. The bottles are then incubated at a temperature of 100° F. and the milk is maintained at this temperature, coagulating in fifteen to eighteen hours. In order to obtain the full therapeutic benefits from this type of milk, it should be consumed within forty-eight hours while the organisms are still vigorous.

(6) **Leben.**—This milk has been prepared for centuries by the Egyptians from the milk of cows, goats, or buffaloes. It is fermented by the growth of yeasts and lactic-acid bacteria. The characteristic flavour is produced by the growth of other organisms in the milk, which are not always necessary to the process of fermentation.

(7) **Kaeldermalk.**—This is a Norwegian product, the name meaning "cellar milk." It is produced by inoculating boiled milk with a special variety of ropy milk, the resultant product being stored under exceptionally cool conditions. Large quantities of lactic acid and alcohol are eventually formed, which enable the product to keep well. For this reason, it is often used as a substitute for fresh milk by the Norwegian peasantry.

Buddeised Milk

This milk derives its name from the Danish engineer, Budde. During the processing, the milk is treated for several hours at a temperature of 125° F., with 0·35 part per 1,000 of hydrogen peroxide. The milk is initially stirred and the bacteria present are subjected to the simultaneous action of heat and poison. The hydrogen peroxide decomposes into water and oxygen and destroys the bacteria. The quantity of chemical added depends upon the catalase content of the milk and the number of bacteria present. Commercial 3 per cent. hydrogen peroxide cannot be used because of the poisonous impurities which it contains, and also because it would seriously add to the moisture content of the milk. Pure hydrogen peroxide must be used, which renders the method exceedingly costly and impracticable from a commercial viewpoint.

Iodised Milk

This is milk to which organic iodine has been added which has been prepared and marketed in the United States of America. Iodine is considered by biologists to be an indispensable adjunct to human diet, if various deficiency diseases are to be prevented. Organic iodine must not be confused with tincture of iodine and other inorganic compounds, which are drugs. It is a catalytic agent which is rapidly used up in body functions, expending itself upon the destruction of disease-producing organisms and the neutralisation of toxins. It must be constantly renewed if these processes are to be continued. Milk to which a 5 per cent. organic iodine solution has been added is of definite value. The substance is incorporated in the milk in the ratio of 1 gallon per 10,000 quarts. This gives the milk an iodine content of 9 mgms. per quart. This is sufficient to assist materially in the absorption and assimilation of the calcium, phosphorus, and magnesium in the milk, these elements being inadequately assimilated in the absence of iodine. The organic iodine passes readily from the digestive tract into the blood-stream, and exercises a high bactericidal power in combating plasma toxins and disease-producing organisms which are commonly present in the digestive tract.

Junkets

Junkets of various kinds are popular dishes, and are especially suitable for invalids who cannot consume solid foods. In preparing this product, the milk is heated to approximately 98° F., when it is poured into dishes,

sugar being added, together with a small quantity of essence of rennet. The milk will curdle and "set" in some two hours. When firm, a layer of cream is usually employed to cover the surface of the junket. Various fruit juices or flavours are now incorporated in junket powders, these adding to the palatability of the finished article. The rennet may be obtained either in tablet or powdered form, being usually sold as junket powder. The powder is generally preferred to liquid rennet, since the latter often varies in strength, more material being required to curdle the milk at one time than at another, following variations in climatic and other conditions.
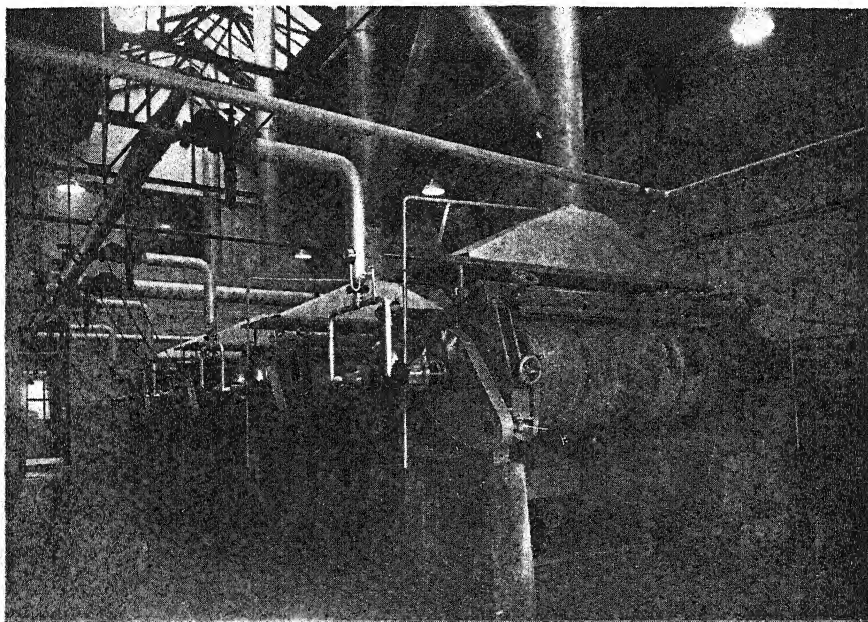
By courtesy of the Milk Marketing Board

FIG. 79—Whey Roller-drying Plant

Dried Whey

After several years' research, it has been found possible to produce dried whey, and a dried mixture of whey and separated milk. These products are often manufactured by the roller-drying and spray-drying processes described on pages 283 to 299, the liquid being concentrated prior to submission to the drying process in vacuum pans under reduced pressure A modified form of dough drying has also been used, the liquid being condensed in a special type of vacuum pan until it assumes the form of a paste. In the drier, the paste is kept in motion by revolving arms and the stiff product which results is run into moulds where it sets to form a crystalline cake which contains 10 to 18 per cent. of moisture. The chief difficulty which had to be overcome was the caramelisation of the lactose in the whey.

One of the most popular types of this particular apparatus is the *Scott Vacuum Band Drier*. In this plant, there are from four to eight endless woven-wire bands, which are driven by rollers. These rollers are arranged horizontally within a long vacuum chamber. The
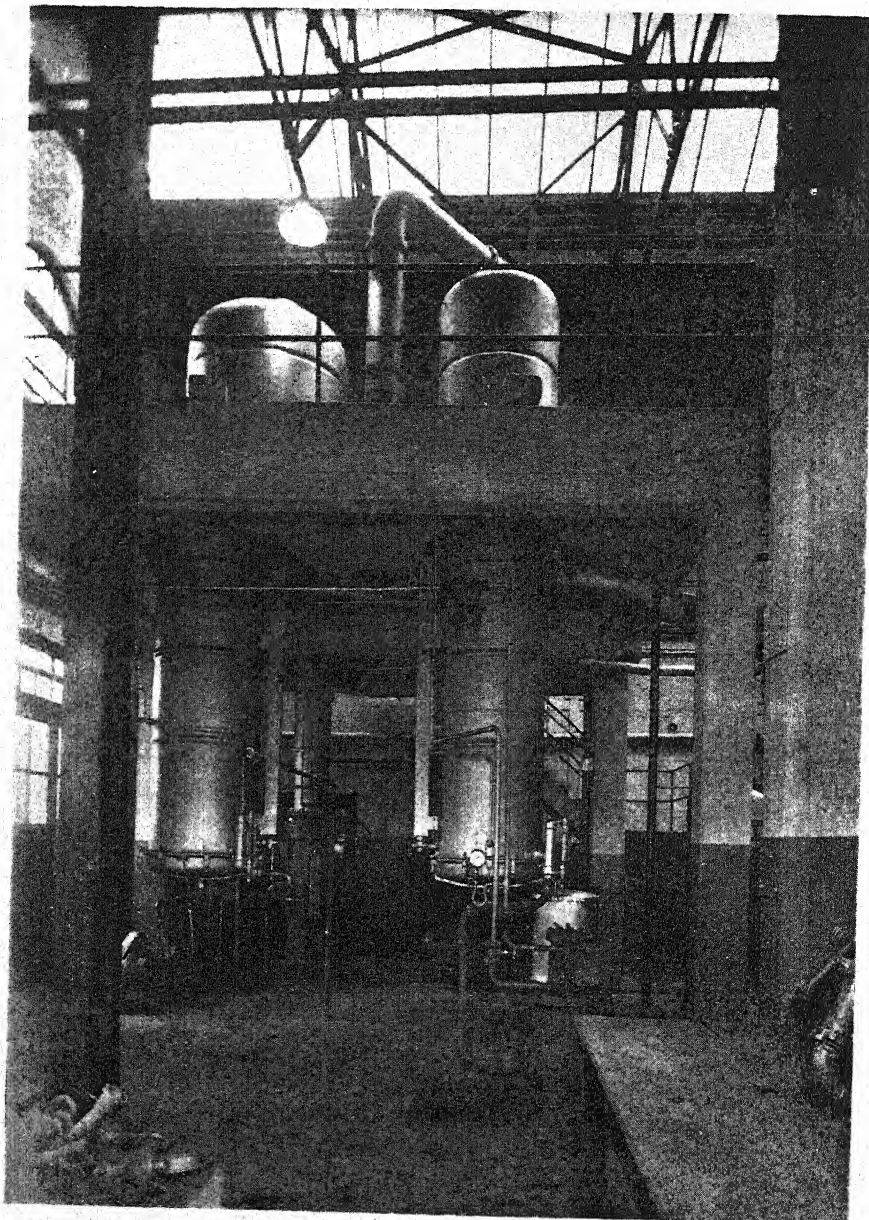
FIG. 80—A.P.V. Whey Condensers

bands are constructed of nickel or monel metal. The upper portion of
each band slides over a hot-plate, through which steam or hot water is
circulated. Whey, previously concentrated to about 65 per cent. solids
under pressure, is fed on to the bands by special spreading feeders.
The whey on the belt passes through the vacuum chamber, in which
a high vacuum of at least 29 inches is maintained. On leaving the
apparatus, the dried whey is scraped off the band and drops through a

breaking apparatus into a receiver situated below the plant. The vapours which arise are drawn off to condensers. The powder is then ground and packed under vacuum.

The advantages claimed for this process are:

(a) A larger heating surface is provided than can be employed in a drum drier of similar size.

(b) The whey never comes into contact with the heating surface, as it is on the upper surface of the moving band.

(c) As the whey is preconcentrated to approximately 60 per cent. of its solids, it can be dried very quickly.

With a suitable product, a non-hygroscopic powder which contains approximately 2 per cent. of moisture is produced.

The utilisation of the whey in this and other ways to be mentioned later has been of considerable value to cheese manufacturers. The farm-house cheese-maker used the whey produced for feeding pigs, but, because of the enormous quantities of the liquid resulting from cheese manufacture upon a large scale, amounting in many cases to several thousands of gallons per day, this method could not be continued. Considerable quantities of whey were thus allowed to run to waste, polluting the streams in the vicinity.

Dried whey is largely used by bread-bakers, the flavour, texture, colour, and volume of loaves to which it has been added being thus appreciably improved. There is still further scope for the use of dried whey in industry. Owing to its high water content about $\frac{3}{4}$ lb. of powder per gallon of whey is produced. It possesses a salty flavour due to its high common salt content which is approximately 2·5 per cent. of the whole, and this affords a simple test for differentiating between dried skimmed milk and dried whey. It is a white, slightly sweet powder which will keep almost indefinitely if retained in a dry condition. It is extremely digestible and possesses a high lactose, calcium and phosphorus content and is rich in vitamin B_2.

Lactalbumin

This is a nitrogenous substance composed of carbon, nitrogen, hydrogen, oxygen, and sulphur. It resembles the white of egg and coagulates if heated to 158° F. It will not clot if rennet or acid is added. Lactalbumin is a protein which yields many amino acids upon hydrolysis, e.g. leucine, systine, glutamic acid, proline. It is one of the most efficient proteins for supporting growth.

Lactalbumin is obtained from whey which would otherwise be wasted, and is now used in the manufacture of many medicinal preparations. The whey is heated to 203° F., causing the albumin present to coagulate. This is removed from the liquor by filtration, the albumin being ground with a measured quantity of deci-normal alkali, the mixture being afterwards dried in vacuo. The dried product contains some 5 per cent. of sodium hydroxide, and is reasonably soluble in water. The alkali albuminate is precipitated with hydrochloric acid, and the precipitate is thoroughly washed to remove all traces of sodium chloride. It is then redissolved in dilute alkali. A dried product containing 2 per cent. of sodium hydroxide is finally obtained, the product being readily soluble in water.

Lactose

The principal product of whey is lactose or milk sugar. This is present in milk in quantities up to 5 per cent. of the whole. It is much less sweet

than cane sugar, but does not ferment, and is particularly useful for medicinal purposes. It is regularly used in the bulking of medical preparations in the form of tabloids or pills. It is easily assimilated and is often used in the preparation of humanised milk.

Lactose may be prepared from whey or from the filtrate obtained in the production of lactalbumin previously described. If obtained direct from whey, the liquid is heated in order to precipitate the albumin. It is then mixed with calcium hydroxide and evaporated until a syrup is formed. This syrup crystallises in one or two days, the crystals being washed in a centrifugal machine and dissolved in hot water. The liquid is then heated to 170° F., filtered through charcoal, and the filtrate is dried at 140° F. and powdered.

If the albumin is not removed from the whey, the method employed is somewhat different. The whey is concentrated in vacuum pans similar to those used in sugar factories, after which it is cooled and allowed to stand for twenty-four hours. A mass of fine crystals is formed, the crystals being covered with an oily layer. The mass is diluted with cold water and centrifugalised to separate the crystals. A crude, yellow-coloured milk sugar is produced, containing 88 per cent. of lactose. This is carefully washed in cold water and refined. The process of refining is carried out in the following manner. The crystals are mixed with bone black and a small quantity of acetic acid, and the mixture is boiled. During this process 0·2 per cent. of magnesium sulphate is added. This treatment decolorises and deodorises the sugar, the acid precipitates any albumin, while phosphoric acid is precipitated by the magnesium sulphate. The liquid is then filtered and is afterwards concentrated in vacuo and recrystallised. It is afterwards further refined to obtain the lactose in the form of a very fine white powder.

The employment of lactose as a medium upon which the mould of *Penicillium notatum* is cultivated in the preparation of penicillin has encouraged the production of lactose from whey. It has been stated that the best medium for the cultivation of this mould is lactose dissolved in corn liquor, and this has been used in the United States and in other countries for this purpose.

Whey Foods

Animal foods produced from whey enjoy a ready sale. The liquor remaining after the lactose has been extracted is used in their production. This liquor contains some 13 per cent. of lactose, 10 per cent. of protein, a varying quantity of inorganic salts and acids, and moisture. The liquid is condensed in vacuo to a specific gravity of 1·2 and is then mixed with brewer's grains. The final product is composed of half whey solids and half brewer's grains, and is roller-dried. The dried mixture is broken up and sold for feeding pigs. The composition is approximately as follows:

	Per cent.
Albuminoids	18·08
Oil	2·10
Carbohydrates	52·37
Crude Fibre	8·15
Moisture	9·78
Ash	9·52

Whey paste is often made from the liquor by concentrating to a specific gravity of 1·4. This results in the production of a semi-solid mass which contains 34 per cent. of moisture. This is sold in barrels for animal feeding. Whey is sometimes pasteurised at a high temperature and is then soured for twenty hours at 106° F. by the addition of *Thermobacterium helveticum* The mass is thoroughly stirred during the souring process and is finally evaporated to one-third of its bulk. This substance is packed in barrels for the feeding of cattle.

Infant and Invalid Foods

Innumerable infant and invalid foods are prepared from milk. Most of these foods make use of dried whole-milk as a basis, the milk so used being dried by one of the many methods described in Chapter VII. The mode of preparation is similar in most instances, differing only in certain minor respects. Some foods exhibit additions, of which lactose and milk-fat are the chief, while others have certain constituents, chiefly milk-fat, removed from the milk prior to drying. Table 15 sets out the average analyses of the principal foods which have been sold for infant and invalid feeding. *Cow & Gate* foods can be obtained in full-cream, half-cream, or humanised types, according to the purpose for which they are required. *Allenbury's No. 1* food is composed of dried whole cow's milk from which a certain proportion of the protein has been removed, but to which lactose and cream have been added. *Glaxo* is dried whole-milk to which has been added cream and lactose. *Humanised Trufood* is a modified dried milk in which the ratio of the protein has been adjusted to approximately equal proportions of casein to lactalbumin plus globulin. The War has reduced to a certain extent the sale of proprietary infant foods, during which time the Ministry of Food introduced their own grade of full-cream dried milk for infant feeding. This is in great demand on account of its low price, and it is readily obtainable.

Milk may be treated in innumerable ways to render it suitable for invalids and older children. *Benger's Food*, containing wheat flour and pancreatic extract, may be mixed with whole-milk to form a suitable invalid food, while *Horlick's Malted Milk*, the manufacture of which is described below, is often prescribed for a similar purpose. *Mellins' Food* is a type of desiccated malt extract. *Chocolate and Milk*, with or without added ingredients, is a popular invalid food. It is prepared by adding predigested wheat, sugar, and chocolate to dried whole-milk. The product is usually packed in tins and, when reconstructed, provides a nourishing and refreshing drink. *Ovaltine* and *Bournvita* are proprietary foods of a similar type, containing a percentage of malt.

Malted Milk

The preparation of malted milk combines the technique of dried-milk manufacture with that of the brewer, the process consisting of the combination of milk with the liquid resulting from a wash of barley malt, and wheat flour.

The process may be divided into the following stages:

(1) Production of Mash Liquor.
(2) Mixing with Milk.
(3) Dehydration.

(1) **Production of Mash Liquor.**—Barley malt is invariably used because of its pleasant flavour. It is important that grain of the highest quality should be used, as lower-grade grain will not germinate properly, and will result in an insufficiency of enzymes. The barley is screened and cleaned to remove impurities, particularly dust, which adhere to the grains. It is then steeped in water, being held in large tanks and submerged to a depth of 1 foot, during which period the material swells and absorbs 25 to 35 per cent. of moisture. The period of submersion varies from one to three days, according to the type of grain used and the nature of the water. The water must be frequently changed. Barley containing a high percentage of moisture is often given a preliminary kilning to reduce the moisture content. This is done by heating the barley from 100° to 120° F.

The barley must then be allowed to germinate. Malting is generally carried on by means of machinery, rendering the operation free from any restrictions of climate or temperature, but the open-floor method is still used. In this latter method, the barley is spread on open floors to a depth of 8 to 10 inches. The mass is frequently raked to provide aeration, and is occasionally sprinkled with water when the process of germination has commenced.

Two mechanical methods are in use:

(1) *The pneumatic-drum system*, which makes use of a slowly rotating horizontal drum, inside which the grain is gently agitated. During the process, conditioned moist air is fed into the drum, being afterwards carried away by suitable air ducts.

(2) *Large tanks with perforated floors*, upon which the grain is spread to a depth of 2 feet. Moist air is drawn through the floor by means of fans, the material being stirred mechanically and sprinkled with water when necessary.

Germination must not take place too rapidly, temperature and period being important. The usual temperatures and periods are:

(1) Home-grown Barley: 65° F. for ten to eleven days when germinated upon the floor.

(2) Foreign Barley: 70° to 75° F. for a similar period.

When germination by machinery is in operation, the period is reduced to six or seven days. The results of germination may be tabulated as follows:

(1) The optimum percentage of diastases is produced for rapid conversion of the starch into dextrins and maltose. A high maltose content is desirable.

(2) Proteolytic enzymes are produced which break down the protein content of the grain into soluble and easily assimilable peptones and related bodies.

(3) Cystase is developed, which dissolves the cellulose tissue of the starch cells and releases the contents in such a form that the diastase readily acts upon them.

After germination the grain is transferred to a kiln, where its moisture content is reduced to 3 per cent. by spreading upon a series of perforated floors through which hot air is drawn by means of fans. A drying temperature of approximately 80° to 90° F. is employed for the first few days after which the temperature is increased to 120° F. for the full drying period of four days. If the grain is germinated by means of the drum process, it is dried in the drum after germination has been completed.

The malted barley is crushed, the crushed material being mixed with high-grade wheat-meal or flour. The mixed grains are "mashed" with cold water and the temperature of the mixture gradually increased until 160° to 165° F. is reached. The mashing process occupies several hours,

TABLE 18

Product	Fat	Protein	Carbohydrate	Mineral Salts	Moisture	Description
Cow & Gate Full-cream Food	27·3	26·6	37·6	6·0	2·5	A standardised unmodified milk food suitable for feeding normal children up to 9 months
Cow & Gate Half-cream Food	15·0	20·0	58·0	4·5	2·5	A milk food with reduced fat for children up to 3 months and older fat-intolerant infants
Cow & Gate Humanised Food	26·5	13·6	54·7	3·2	2·0	A milk food with increased carbohydrate and decreased protein
Glaxo	26·5	24·9	38·5	5·6	2·9	Dried milk (unmodified)
Humanised Trufood	28·24	12·40	52·24	5·42	1·70	Dried milk modified
Ambrosia	28·96	26·80	36·85	5·64	1·75	Dried milk without modification
Lactogen	25·0	16·2	53·3	3·5	3·5	Dried milk modified by the addition of lactose
Dorsella	27·13	22·33	42·34	5·95	2·25	Dried milk modified by the addition of lactose and fat
Allenbury's No. 1	18·5	9·7	62·3	3·8	5·7	Dried milk with decreased protein. Lactose and cream added
Allenbury's No. 2	15·0	9·2	69·1	2·5	3·9	Same as No. 1, but with malt added
Horlick's Malted Milk	8·78	16·35	67·95	3·86	3·06	A milk-and-malt powder for general feeding
Ovaltine	8·0	14·2	67·9	—	—	Malt, milk, and eggs flavoured with cocoa

the insoluble husk being removed by passing the mash through a centrifugal separator. During this process, the whole of the starch is hydrolysed by diastase into maltose, dextrin, and malto-dextrins, while the complex cereal proteins are converted into simpler protein substances.

(2) **Mixing with Milk.**—Pure, clean, fresh milk is required, and, in order to produce a malted milk with a standard composition, strict analytical control is essential. Milk which has been reconstituted from dried milk cannot be considered satisfactory for use in the manufacture of this product, as such an article lacks certain essential properties usually associated with malted milk. The milk and the liquor derived from the mashing process are mixed together in vacuum evaporators.

(3) **Dehydration.**—The mixed liquids in the evaporators are heated until approximately one-half to two-thirds of the water content has been removed. The product is then transferred to steam-jacketed evaporators, each of which is provided with stirring gear. A high vacuum is maintained, agitation being constant in order to facilitate the removal of the water and to prevent excessive caramelisation. The final evaporation process removes the remaining moisture, when a sponge-like, swollen mass is formed. This is removed and reduced to a powder, after which it is ready for packing. At this point, care is necessary in order to prevent absorption of moisture from the atmosphere. Any absorption of moisture will impair the keeping qualities of the product.

Malted-milk powder will dissolve freely in hot or cold water or milk, the resultant beverage being extremely palatable, besides possessing an agreeable odour and flavour which are derived from the hydrolysed cereal starch used in its manufacture. *Horlick's Malted Milk* contains 33 per cent. dried milk, and the hydrolysis products of wheat flour and barley malt. An average analysis in terms of fat, proteins, carbohydrates, etc., will be found set out in Table 18.

Other Milk Preparations

Peptonised milk is prepared by adding the digestive ferment, pepsin, to milk. The pepsin partially digests the casein and prevents the formation of a casein curd. The milk used for the peptonising process is usually diluted, as, by this means, the action of the clotting ferment is obviated. Peptonised milk is exceedingly digestible, the pepsin being added to either hot or cold milk in the form of a powder.

Citrated milk is another type of milk prescribed for invalids. It is prepared by adding one or two grains of sodium citrate to each ounce of milk to be used. A light, finely divided clot is produced, which renders the milk exceedingly digestible.

Humanised milk is becoming exceedingly popular for infant feeding. Cows' milk, although it contains many of the nutritive properties of human milk, differs in composition from the human product. The average compositions of human milk and cows' milk are set out below:

	Human Milk. Per cent.	Cows' Milk. Per cent.
Fat	4·13	3·5
Proteins	2·00	3·33
Sugar	6·94	4·65
Ash	0·20	0·72
Water	86·73	87·80

It will be seen from the above table that cows' milk contains more protein and ash, but less fat and sugar, than does its human counterpart. The protein in cows' milk also contains a lower proportion of lactalbumin, while the ash contains less iron.

Humanised milk may be prepared by the addition of water, cream, and lactose to cows' milk. One part of water to two parts of satisfactory-quality whole-milk will reduce the protein content to suitable proportions, while cream must be added to increase the fat content until it approximates to that of human milk. The usual proportions are 10 ozs. of cows' milk, 1 oz. of cream, 1 oz. of lactose, and 10 ozs. of water. A close approximation may be obtained by substituting whey, which contains albumin or lactose, for water. The quantity of whey should equal one-third of the volume of the milk prepared. Infant foods prepared to the standard of humanised milk may now be obtained, and it is claimed that these closely resemble human milk when reconstituted.

Casein

This is the principal albuminoid found in milk, its composition being as follows:

	Per cent.
Carbon	53·57
Hydrogen	7·14
Oxygen	22·03
Nitrogen	15·41
Sulphur	1·11
Phosphorus	0·74
	100·00

While the casein content of milk varies, being in the neighbourhood of 3 per cent., it forms approximately 80 per cent. of the protein content of the liquid. It is coagulated by the addition of rennet or acids to milk, but not by heat, differing from albumin in this respect. It exists in a colloidal state, that is, in a state of fine suspension, so fine that it cannot be removed from milk by the ordinary methods of filtration.

The quality of casein is dependent upon the observance of certain factors, whichever type is manufactured. These are:

(a) Quality of the milk used.
(b) Cleanliness of the vats, presses, and other equipment.
(c) Accurate temperature control during precipitation, washing, and drying.
(d) Control of acidity to the proper end point.
(e) Production of a well-washed curd with a low free-acid content.
(f) Elimination of the maximum amount of moisture before it is milled and dried.
(g) Uniformity in drying.
(h) Suitable storage methods.

When rennet casein is manufactured, in addition to the above factors, the following points are of considerable importance:

(a) The setting temperature.
(b) Kind, age, and care of the "starter."
(c) Method of adding the "starter."
(d) Cooking temperature.

The following additional factors are also of importance when acid-precipitated casein is produced:

(a) Precipitating temperatures.
(b) Dilution of the acid.
(c) Method of adding acid.
(d) Amount of acid employed.

Acid-precipitated casein is obtained on a commercial scale from skimmed milk, which should be as fat-free as possible. This is heated to 90° F., the casein being precipitated by the addition of hydrochloric acid. The milk is continuously stirred and acid diluted in the proportions of one of acid to eight of water is sprayed on the liquid until the milk breaks into clots, when the rate of stirring is increased. When the milk has coagulated, the curd is broken up and half of the whey drained off. Further quantities of acid are added until the mixture has a pH value of 4·6 to 4·8. The casein is drained into a cheese cloth and washed by completely covering with water which has been acidified to pH 4·6, stirred and drained. This process is twice repeated and, after a final draining, the product is pressed, milled, and then dried on trays in thin layers, in tunnel driers, with air at a temperature of 120° to 125° F. Casein produced in this manner contains from 6 to 8 per cent. of moisture and between 1·4 and 2 per cent. of mineral matter.

Rennet casein is prepared by warming the skimmed milk to a temperature between 100° and 104° F. in a vat and rennet solution is added. This is prepared by diluting ordinary rennet to obtain a 5 per cent. solution, about 10 mls. being added for each gallon of milk. The amount of rennet added is sufficient to ensure coagulation takes place in about thirty minutes' time. The curd settles to the base of the vat above which is a clear liquid. The curd is cut and the mixture heated to nearly boiling point to destroy the rennet. The whey is drained off and the curd, after piling, is washed three or four times with cold water after which it is drained, pressed, ground, and dried. This type of casein contains between 5 and 9 per cent. of moisture and about 8 per cent. ash.

Natural-soured casein is manufactured from neutralised skimmed milk which is warmed to 104° F. and allowed to sour naturally until it possesses an acidity of 0·64 per cent. The casein is precipitated and is cooked at 120° F. after which it is thoroughly washed, pressed, ground and dried. Casein should be stored in a dry atmosphere, protected from moisture, mould spores and the depredations of vermin and insects. It is usually packed in jute sacks or cardboard or wooden containers.

Casein can be utilised for innumerable purposes. Powdered casein is used as the basis of a number of proprietary food preparations, such as *Vitafer* and *Sanatogen*. Several of these preparations contain as much as 95 per cent. of casein. A considerable business in hardened casein is now carried on. The casein is exposed simultaneously to pressure and heat, and is subsequently hardened with formaldehyde to any extent required. A plastic substance is thus formed which can be used for a variety of purposes. It may be moulded into simple articles or made into sheets, rods, tubes, or bars. It is used in the preparation of artificial celluloid, knife handles, imitation ivory, buttons, cigarette holders, combs, electrical accessories, fountain pens, radio components, spectacle frames, billiard balls, piano keys,

and numerous other articles.   It can be beautifully coloured and highly polished, while it is odourless, non-inflammable, and can be drilled, sawed, or turned on a lathe.   The manufacture of imitation jewellery is one of the more recent developments of casein.

Casein is also used to produce a highly polished finish on paper by dissolving in borax and ammonia, either separately or in combination, or with trisodium phosphate, followed by mixing with china clay.   It has displaced several other adhesives for this purpose.   It is used in the manufacture of a certain type of glue, which is exceptionally resistant to water and high temperatures, by mixing with hydrated lime.   This glue is used in aeroplane construction, and its use has been extended to pianos and furniture which are to be exported to tropical countries, and in the production of motor bodies where a moisture-proof material is essential.   It is also used for pasting labels on bottles which are to be kept in ice or in cold water.

When it is mixed with hydrated lime or other alkalis, pigment filler, and cold water, casein makes a paint suitable for wood, stone, cement, and metallic surfaces.   It dries very quickly and can be applied during unfavourable weather, while it will withstand rainwater in a remarkable manner.   It is used in the textile-printing industry to fix the colours, and, when combined with powdered mica, imparts a metallic lustre.   If applied to light leathers, it produces a polished surface.   It is added to liquid insecticides to enable the liquid to spread over the leaves of plants and adhere when dry.

The Control of Casein (No. 1) Order, 1942, which came into operation in September of that year, prohibits the disposal of acid or lactic casein except under the authority of a licence or a direction of the Ministry of Supply.

Milk Chocolate

A large quantity of milk powder is used annually in the manufacture of milk chocolate, which contains varying proportions of milk products.   Milk chocolate of good average quality contains from 15 to 25 per cent. of milk solids.   No legal standard has been fixed in this country, but in the United States of America milk chocolate must contain a minimum of 12 per cent. milk solids.   The composition varies greatly with different manufacturers, but, on an average, it may be stated that milk chocolate consists of:

	Per cent.
Milk Solids	25
Cane Sugar	40
Cacao Butter and Cocoa Mass	35

Knapp gives the following average composition:

	Per cent.	Calories per lb.
Milk-fat and Cacao Butter	35·0	1,480
Milk and Cocoa Proteins	8·0	149
Starch and Digestible Carbohydrates	3·0	56
Theobromine and Caffeine	0·2	—
Mineral Matter	2·0	—
Crude Fibre	0·3	—
Moisture	1·5	—
Milk and Cane Sugars	50·0	930
Total	100·0	2,615

Continental chocolate usually contains a higher percentage of milk-fat and milk sugar. In addition to the high calorie value, milk chocolate contains an appreciable proportion of milk with all its intrinsic properties. One pound of milk chocolate contains the equivalent of $1\frac{1}{2}$ pints of full-cream milk.

The milk is not used in its liquid form, as it is obviously advantageous to buy milk only when there is a surplus, and when the product is cheap. It is therefore essential that the product should be stored in some form until required. Different manufacturers have adopted various methods of storage, but, whatever method is used, the milk should always be kept in such a condition as to render an intimate mixture with the other ingredients possible. Some factories dry the milk and incorporate the dried product with the other ingredients. The milk is sometimes stored in the form of *blockmilk*. This is a highly concentrated, sweetened milk which is moulded into blocks and covered with cacao butter. Milk, to which 10 per cent. of sugar has been added, is evaporated to a concentration of 40 per cent. The resultant product keeps perfectly and is used both by chocolate and sweet manufacturers. In other factories, a mixture of milk and cocoa mass is dried, the resultant mass being broken into lumps and stored in special silos until required for use. When used in manufacture, this dried mass is mixed with sugar and cacao butter in the usual way. The mixture is passed through grinding machines and conches, which reduce the mixture to an extremely fine state of division. The heat of the grinding and conching processes is sufficient to retain the mixture in liquid form. The finished material is then moulded and hardened as required.

The food value of milk chocolate depends upon the food value of each of its constituents, as follows:

(1) *Cacao Butter.*—The nutritional value of this article has been the subject of much investigation. It has been proved that it is only slightly less digestible than dairy-butter fat. In addition, its digestion is facilitated by the presence of the sugar in the chocolate. Chaplet has reported on the result of digestion tests of cacao and dairy butters, and claims that cacao butter is assimilable to the extent of 98 per cent., as against an assimilation of 95·8 per cent. in the case of dairy butter. The presence of high percentages of cacao butter will, however, undoubtedly delay gastric secretion and may thus give rise to dyspepsia.

(2) *Proteins.*—The proteins in cocoa are stated by Jensen to be mainly of a globulin type. Recent experiments have shown that only one-third of the nitrogen is in digestible form, soluble in the gastric juice. Another third is amino and alkaloidal nitrogen, the remaining third being non-assimilable. Mitchell, Beadles, and Keith have shown that the relative food value of milk chocolate per 100 parts of the product is 5·1 as against 19·2 of full-cream powder. These workers have also shown that the percentage of cacao proteins used dietetically is 14 per cent. compared with 80 per cent. of the proteins of milk.

(3) *Stimulants.*—Milk chocolate, as with all cacao preparations, contains significant quantities of theobromine and traces of caffeine. Four ounces of chocolate will contain 8 grains of theobromine, equal to a full medicinal dose. This, however, is quite harmless. Theobromine is oxidised and broken up by the body into uric acid and other derivatives, which are excreted. It exercises a diuretic action and has a very slight effect upon the cardiac muscle. It also increases the body's capacity for work. The gastric disturbances which can accompany the continued use of cacao products are thought to be due to the theobromine acting upon the gastric mucous membrane, with a subsequent delay of hunger and of the necessary secretions.

The stimulant effect of theobromine and caffeine makes chocolate highly suitable for the nervous systems of children, and a good tonic for the old.

(4) *Vitamins.*—These are derived from the milk solids and the cacao mass. It has been proved by investigators that chocolate contains an appreciable

quantity of vitamin A, while the presence of vitamin B has also been reported. In experiments conducted by Sasika and Wakayama, it was found that 3 grams of chocolate per day were sufficient to cure an anti-neuritic deficiency in pigeons. Knapp and Coward have shown that vitamin D is present in material concentration.

In addition to its value as a food, milk chocolate is used for improving the taste of laxatives and for the coating of pills of various types.

Various Minor Uses of Milk

New uses for milk are continually being discovered and employed commercially. In Holland, prior to the War, a new form of *milk in cubes* was introduced after considerable research by manufacturers of dried milk into the question of preserving the liquid. The milk is separated from the cream and desiccated to a powder by evaporating 90 per cent. of the moisture content. The cream which has been removed is then added to the powder, which is compressed into small cubes. These are said to be remarkably soluble and to possess extremely satisfactory keeping qualities. When the cubes are dissolved, it is claimed that the reconstituted milk presents all the qualities of fresh milk. If this method of treating milk were proved to be satisfactory, the product could be treated in this way when supplies were abundant.

In view of many complaints received in the past that a large quantity of liquid milk supplied to schools was wasted, the Ministry of Food are carrying out certain experiments in four counties of Great Britain, one of which is situated in Scotland. This involves the use of powdered milk compressed into blocks and flavoured with raspberry, lemon, chocolate, or other flavours. There are nine flavours in all and three types of blocks, each of which contains the equivalent of one-third of a pint of milk as previously supplied. They can be eaten like biscuits and have been accepted with enthusiasm at those schools where they have been introduced.

Still another use for milk was found in ship-repairing yards on Tyneside. In the repair of a certain vessel, the contract specified that the *cement wash* used for the tanks must be composed of cement and milk instead of the usual cement and water. In this particular contract, 45 gallons of skimmed milk were used. Following the application of the mixture, the surfaces so treated presented a glazed appearance, while the fat in the milk was thought to have additional useful properties.

An Italian scientist, Dr. A. Feretti, invented a method known as the "Lanital" process, of obtaining *wool from the casein of milk*. In Italy, plans have been made to manufacture this article upon an industrial basis, and, prior to the War, a factory was opened at Milan which produced up to 30 tons of "Lanital" per day. A number of Continental countries also acquired manufacturing licences from the inventor. "Lanital" may may be mixed with natural wool or with cellulose. Such a process possesses certain points of interest. For countries which cannot find an outlet for their total milk supply, the manufacture of wool in this manner may possess great economic possibilities; indeed, such an industry may yet assume an importance equal to that of the artificial silk industry. The actual process is patented and is entirely secret. The raw material used is skimmed milk, which is curdled by the addition of sulphuric acid, the casein being then separated, washed, and pressed. The process of transforming the casein

into wool is analogous to that used in the manufacture of artificial silk. It
is probable that the process is carried out in the following stages:

(1) Dissolution of the casein.
(2) Ripening.
(3) Drawing.
(4) Drying.

Skimmed milk yields approximately 3 per cent. of wool. The weight of the
wool obtained is almost the same as that of the casein employed. A similar
product was manufactured in Czechoslovakia and in Holland prior to the War.

Technical experts of the United States Bureau of Dairy Industry have
assisted in the production of *synthetic rubber* by perfecting a process for
making a transparent rubber-like substance from the lactic acid of whey.
This substance, chemically known as poly-methylacrylate, is a water-white
semi-solid material which is soft and extremely flexible, but at the same
time tough and elastic. All types of fabrics, paper and other materials
may be coated or impregnated with this substance to render them resistant
to water, oil, or gas. Production costs are said to be extremely low.

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